THE EFFECTS OF HIGH INTENSITY INTERVAL TRAINING ON WORKING MEMORY PERFORMANCE IN SENDENTARY YOUNG ADULTS

By: Ashley August Averett

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

in Psychological Sciences

Northern Arizona University

May 2017

Melissa Birkett, Ph.D., Chair

Steven Barger, Ph.D.

Sara Jarvis, Ph.D.

ABSTRACT

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ASHLEY AVERETT

Aerobic excise interventions improve working memory performance among older adults and in clinical populations. The present research seeks to extend these findings by investigating the effects of an 8-week high intensity interval training aerobic exercise intervention on the working memory performance of sedentary but otherwise healthy young adults. Working memory performance was assessed pre-intervention and post-intervention using three distinct tasks: the Psychology Experiment Building Language (PEBL) reverse digit span task, the PEBL visual-response memory span task, and the PEBL symmetry span task. It was hypothesized that working memory performance, as measured by a maximum span on each task, would improve following the exercise intervention. Preliminary results (N = 6) do not indicate improvements in working memory performance. No difference was found in reverse digit span, visual-response memory span, or symmetry span task performance. Future studies should continue to contribute to understanding effects of aerobic exercise interventions on working memory performance of sedentary but otherwise healthy young adults.

Acknowledgements

This thesis project would not have been possible without the hard work of many talented individuals at Northern Arizona University. First, I would like to extend my immense gratitude to my thesis chair, Melissa Birkett, Ph.D., for her steadfast guidance and support throughout the entirety of this project's conception, implementation, and completion. Dr. Birkett served tirelessly as a stable source of motivation and kindness throughout every aspect of this project. This accomplishment, along with many others, would not have been possible without her. I would also like to thank Sara Jarvis, Ph.D., for her constant guidance, particularly in the implementation of the broader P.I.C.E.S. study. Dr. Jarvis graciously welcomed me into her Cardiovascular Regulation Laboratory, allowing me to pursue interdisciplinary research in way that would not have been possible without her support. In addition, Dr. Jarvis was crucial to the organization and implementation of the H.I.I.T. exercise intervention central to the P.I.C.E.S. study. Next, I would like to thank Steven Barger, Ph.D., for his incredibly helpful guidance in the development of the original research questions, methodology, and data analysis plan.

I would also like to thank other members of the P.I.C.E.S. research team. Christopher Frank, the principle investigator of the P.I.C.E.S. study, was essential to the conception of the project, participant recruitment, implementation of the exercise classes, and pre-intervention and post-intervention data collection. In addition, Christopher organized scheduling for participant visits and attended exercise classes to assist in monitoring heart rate data. Next, I would like to thank Brian Bettner, a member of the P.I.C.E.S. research team who also served as the personal trainer in charge of leading each exercise class and assisting in data collection. All other members of the P.I.C.E.S. research team who assisted in data collection and data analysis were vital to the completion of this project as well. Furthermore, I would like to thank Northern Arizona University's Health and Learning Center for offering the use of their group fitness and personal training facilities.

Finally, I would like to thank Dr. Susanna Maxwell and Dr. Barry Lutz, the founders of the Maxwell-Lutz Community Impact Award, for their support of this project. The P.I.C.E.S. project was funded by the 2016 Maxwell-Lutz Community Impact Award, allowing for the purchase of equipment that was integral to the proposed methodology. On behalf of the entire P.I.C.E.S. team, we are extremely grateful to have been chosen for this award.

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Chapter 1: Introduction

Working memory is generally described as a system or set of subsystems responsible for retaining a limited amount of information for a limited duration of time, often in the pursuit of higher order cognitive tasks such as comprehension and problem solving. Though working memory is considered to have practical limits, it is a dynamic process that can be influenced by many factors such as age (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005), intelligence (Burgess, Gray, Conway, & Braver, 2011), body mass index, and physical activity level (Cournot et al., 2006; Sabia, Kivimaki, Shipley, Marmot, & Singh-Manoux, 2009).

It is well established that general cognitive functioning, including memory ability, tends to decline with age and can be negatively impacted by factors such as a sedentary lifestyle. There is mounting evidence that increased physical activity, specifically aerobic activity, can attenuate some amount of cognitive decline associated with sedentary behavior. In middle-aged adults, higher body mass index was found to be associated with lower cognitive function and faster later cognitive decline (Cournot et al., 2006). Furthermore, the Whitehall II Study, a long-term prospective study, found that obesity throughout midlife (being obese on more than two testing occasions) was associated with lower cognitive functioning near the end of middle age (Sabia, Kivimaki, Shipley, Marmot, & Singh-Manoux, 2009).

It should be noted that nearly all data concerning aerobic exercise and cognition in healthy samples utilized participants in middle or late adulthood. Other studies focus heavily on clinical populations with impaired cognitive functioning. However, research has often neglected the effects of aerobic interventions on working memory in young adults, particularly those with sedentary lifestyles.

The current study seeks to contribute to the narrow collection of research regarding the effect of aerobic exercise interventions on sedentary but otherwise healthy young adults. In the following review of literature, the models and theories used to describe working memory will first be discussed in an effort to provide a theoretical base for the proposed research. Adding to this, key assessment techniques utilized to measure working memory abilities will be described. Next, individual differences in working memory ability will be reviewed as they pertain to higher order cognitive processes such as fluid intelligence. Next, claims that working memory capacity can be improved through training will be evaluated and the effects of physical activity on cognitive performance will be examined. Finally, the objectives and strategies for executing the proposed study will be described and unique contributions to the field pending this research will be discussed.

Working memory

Postle (2006) describes working memory as a subset of processes involved in the active storage, maintenance, and manipulation of information to be retrieved within a brief period of time. Thus, working memory ability is essential for many cognitive tasks (Aronen, Vuontela, Steenari, Salmi & Carlson, 2005). Working memory is considered to have reasonable limits (Cowan, 2005). That is, nearly every conceptualization of working memory accepts that there is some kind of limitation in the amount of information that can be kept active in the working memory system at any given time. In order to study these limits, researchers must design working memory tasks that prevent the participant from engaging in performance boosting strategies (*e.g.,* rehearsing, grouping) by occupying them with interference tasks (*e.g.,* rearranging the order of items) that prevent the full allocation of working memory resources to either storage or processing. This strategy allows researchers to identify a point at which both storage and processing functions of working memory are being utilized at maximum—a working memory “capacity”. However, this “capacity” could have the potential to be expanded. First, it is important to understand the role of working memory in performance on other higher order cognitive skills. It is generally assumed that the theorized limits of working memory inevitably have consequences for other aspects of processing. That is, at least certain kinds of higher order processing should be influenced to some extent by individual working memory capacity.

Working memory and higher order cognitive processes

There is a body of research supporting the notion that working memory plays a critical role in the performance of nearly all complex cognitive tasks. The ability to retain information and use it in a goal-directed manner is necessary to accomplish many tasks. Specifically, the short-term storage component and the executive control components of the working-memory system can maintain some information for immediate use while simultaneously integrating information for long-term storage (Baddeley & Hitch, 2003). These collaborating mechanisms are responsible for the distinct necessity of the working memory system in accomplishing goal-directed cognitive tasks. In fact, one hypothesis proposes that working memory function is indeed the most readily contributing factor in variations in human intelligence (Kane, Cambrick, & Conway, 2005).

One indicator of the suggested relationship between working memory ability and intelligence is the finding intelligence quotient (IQ) test performance can be predicted by increased activity in brain areas found to be activated by working memory tasks, *i.e*. the dorsolateral and medial prefrontal cortex (Conway, Kane, Bunting, Hambrick, Wilhelm & Engle, 2005). Another group of researchers reported that working memory appears to drive fluid intelligence and other higher order cognitive abilities (Wiley, Jarosz, Cushen, & Colflesh, 2011). In fact, some researchers have estimated a shared variance between working memory and fluid intelligence of as much as 50% (Kane, Hambrick, & Conway, 2005; Oberauer, Schulze, Wilhelm, & Suss, 2005).

Models and theories of working memory

While there are many competing theories and models used to describe the working memory system, the Baddeley and Hitch (1974) multi-component model is typically considered one of the most empirically supported. Other competing models, such as Cowan's embedded processes model (1988, 1999, 2005) and Ericsson's long term working memory theory (1995), arose in response to the criticism of the Baddeley and Hitch model.

Baddeley and Hitch's multi-component model

Though the term 'working-memory' was originally used by Miller and colleagues (1960), the concept was adapted by Baddeley and Hitch (1974) to represent a new, multi-component model that, importantly, diverged with the previous modal models of short-term memory. The model developed by Baddeley & Hitch (1974) assumes that each component of the working memory system has a limited capacity in addition to being largely independent of one another in function. Namely, the model emphasizes the dual processing and storing power of working memory. The system as a whole both temporarily stores and manipulates information and provides the necessary link between perception, long-term memory, and behavior.

Three distinct but interacting components comprise the Baddeley and Hitch (1974) working memory system: the phonological loop, visuospatial sketchpad, and central executive. The phonological loop, which is theorized to be responsible for the manipulation of verbal information, encompasses a phonological store as well as a built in articulatory rehearsal process. The phonological store holds speech-based information for several seconds before the articulatory rehearsal process is employed to rehearse information for subsequent storage. The phonological similarity effect, whereby difficulty of recall increases as the phonological similarity of words increases, is a robust phenomenon which is often used as a marker of the phonological loop. Next, the visuospatial sketchpad is said to be responsible for storing and manipulating visual images (*i.e.* shape, color) and spatial information (*i.e.* location, size). Like the phonological loop, the visuospatial sketchpad is limited in capacity (Baddeley, 2003). Lastly, the central executive serves as the coordinating body of the entire system, though it is the least understood of the three proposed components.

Though the phonological loop and visuospatial sketchpad work in tandem, it is clear that the two components are ultimately domain specific. In order to account for situations in which information containing both phonological and visuospatial aspects needs to be processed, a fourth component was added to the model in 2000 (Baddeley, 2000). A third temporary storage subsystem, named the episodic buffer, was included under the central executive to serve as an interface between the phonological loop, visuospatial sketchpad, and long-term memory. This addition by Baddeley allowed for each theoretical subsystem to remain functionally independent of one another (Baddeley, 2003).

Unique contributions made by Baddeley and Hitch's still prevailing working-memory model accounted for various inconsistencies between the previously held 'short-term' memory model and empirical findings. For instance, the Baddeley and Hitch multi-component working memory model explains how short-term memory can be disrupted while information uptake to long-term memory remains possible. That is, through the dual storage and processing nature of the system. This aspect of the model is particularly important for the empirical study of working memory, which will be discussed at more length later. Though the Baddeley and Hitch multi-component model remains dominant in the field, several models and theories have emerged in response to certain criticism. Two of the most prominent are Cowan's embedded processes model (Cowan, 1988, 1999, 2005) and Ericsson's long term working memory theory (Ericsson & Kintsch, 1995).

Cowan's embedded-processes model

Unlike Baddeley's more structured and categorized model of working memory, Cowan's embedded processes model (1988, 1999, 2005) favors more inclusive terminology. For example, this model uses the term "activated memory" which is not limited to the processing of either phonological or visuospatial information like the phonological loop and the visuospatial sketchpad. In addition, activated memory encompasses tactile sensory information, a component that is lacking in Baddeley's model even after the addition of the episodic buffer (Cowan, 2005). The second main facet of Cowan's model (1988, 1999, 2005) is the "focus of attention" which is described as a subset of processes that can retain a limited amount of information to be made available for action (Cowan, 2005). While Cowan generally argues that his model's all-inclusive nature is a benefit, some critics argue that since no specific temporary storage subsystems are defined, the processes are also less defined and thereby reveal less information.

Ericsson's long term working memory theory

Ericsson and Kintsch (1995) made the argument that Baddeley's original model of working memory could not account for highly skilled activities requiring excessive working memory capacity such as expert piano playing and advanced reading comprehension. In response to this claim, Ericsson and Kintsch (1995) developed their long term working memory (LT-WM) theory. This theory emphasizes the hefty working memory demands present in certain but not all activities, as mentioned above. However, Ericsson and Kintsch developed this theory in 1995, prior to Baddeley's addition of the episodic buffer in 2000, which partially addresses these concerns because of the episodic buffer's role in temporarily storing information which exceeds the capacity of the other subsystems.

Though both Cowan's embedded processes model (1988, 1999, 2005) and Ericsson and Kintsch's long term working memory theory (1995) offer their own unique contributions to the understanding of the processes involved in working memory, Baddeley and Hitch's (1974, 2000, 2003) multi-component model of working memory continues to be the most empirically studied and supported given the many nuances of working memory. Thus, for the purposes of the current study, the Baddeley and Hitch multi-component model will serve as the general theoretical underpinning for all future discussions of working memory.

Assessment of working memory

The theories described above offer a glimpse of the theoretical framework on which empirical working memory measures have been designed throughout the years. Consequently, experimental results allow for cultivation of more precise construct validity and have led to the discovery of possible strengths and weaknesses in the original theories. Furthermore, increasingly precise measures of the construct allow for a more clear differentiation of working memory from short-term memory and verbal (phonological) working memory from visuospatial working memory (Baddeley & Hitch, 1974, 2000, 2003). Common assessment techniques used to measure working memory in laboratory and applied settings will be described to demonstrate the context in which working memory discoveries are made.

In general, most empirical tests of working memory require participants to store a given amount of information in the working memory system while simultaneously processing other units of information (a co-task). By combining a simple memorization (storage) task with a more cognitively demanding (processing) co-task, thereby preventing participants from merely rehearsing the given information, researchers are able to examine both storage and processing capacity within a lab setting. In order to achieve this, working memory tasks typically increase in informational load after each successful trial, while continuing to include the demanding co-task, thus increasing in difficulty. Within the field of working memory research, many tasks of this variety are named “span tasks,” such as digit span, reading span, listening span, or computation span.

Reading span tasks generally instruct participants to read aloud several sets of sentences of approximately the same length, one at a time, without having visual access to each previous sentence. Next, participants are asked to repeat aloud only the last word of each sentence that was read. Each time a participant succeeds, an additional sentence is added to the subsequent set. Thus, reading span is calculated based on the largest set of sentences in which the participant is able to correctly recall the final word (Daneman & Carpenter, 1980). Some versions of this task even require participants to assess “true” or false” for each sentence to ensure sufficient processing of each sentence (*i.e.*, to ensure sufficient distraction from focusing solely on the final word in each sentence) (Tirre & Pena, 1992). Though this method does a more thorough job of ensuring constant processing, some research has suggested that performance on reading span tasks could be mediated by variables other than working memory capacity such as reading comprehension skills (Friedman & Miyake, 2004).

Similarly, digit, letter, and word span tasks attempt to shed light on the limits of working memory storage capacity. In these kinds of tasks, participants are presented either visually or audibly with various sets of digits, letters, or words and instructed to recall the items either in the same order in which they were presented (forward span) or in reverse order (backward span).

Digit span tasks are ubiquitous in working memory research because they are extremely easy to administer in many forms and versions. However, not all span tasks achieve the common goal of assessing both storage and processing. Ramsay and

Reynolds (1995) used factor analysis to assess whether or not forwards and backwards span tasks actually assess the same construct, and confirmed that while backwards span tasks are a valid assessment of working memory, forward span tasks simply do not measure the same abilities. The backwards span tasks involve transformation—the mental reversal of items prior to answering—while forwards span tasks do not. Therefore, forward span tasks assess only storage capacity rather than the combined efforts of storage and processing. Later, Reynolds (1997) strongly advised that if both versions are used to assess working memory, they should be scored and scaled separately.

Analogous to reading span tasks, listening span tasks require participants to listen to sentences spoken aloud rather than being required to read them aloud. Some versions of this task involve fill-in-the-blank type sentences to solidify the processing of each sentence. For example, the participant could be read the following sentences: "Snow is very ___", "At dinner we eat ___", "Kittens love to play with ___". The participant fills in the blank after hearing each sentence, then repeats back the last word in each sentence. One notable strength of the listening span tasks is that it may not tax reading and comprehension skills like reading span tasks could. However, simpler digit, letter, or image span tasks can achieve the same goal through added audible components that do not require extensive language comprehension skills.

Some other working memory tasks attempt to measure only visuospatial working memory in an effort to bypass possible language moderators (Corsi block test, Milner, 1971; Visual patterns test, Della Sala et al., 1999). However, by choosing a task that attempts to tap into only visuospatial working memory, researchers could be limiting their assessment of working memory ability. Assessing both phonological and visuospatial working memory (via the episodic buffer or individually), in accordance with the Baddeley & Hitch (1974, 2000, 2003) model, allows a more comprehensive analysis of working memory ability.

Plasticity of working memory

If working memory ability is associated with higher order cognitive abilities such as intelligence, it is important to understand the degree to which working memory can be improved. Promising research in the area of working memory plasticity seems to suggest the possibility of improving working memory capacity through training (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Rudebeck, Bor, Ormond, O'Reilly, & Lee, 2012; Stephenson & Halpern, 2013).

Training efforts have focused on tapping into the flexibility of the working memory system by adjusting the difficulty of a task in accord with the participant's improving or diminishing performance. If the participant's working memory capacity can be continually stretched to new limits, there is great potential to increase overall working memory function. In turn, this progression in working memory abilities could result in improvements in cognitive abilities that depend on the performance of working memory skills or originate from the same structural resources as working memory (Burgess, Gray, Conway, & Braver, 2011).

Jaeggi, Buschkuehl, Jonides, and Perrig (2008) demonstrated that training on challenging working memory tasks not only improved working memory performance, but also had the potential to improve performance on measures of fluid intelligence (*Gf*). Furthermore, the transfer was dose-dependent—the more training on the working memory task, the more improvement on *Gf* measures. *Gf* refers to the ability to use reasoning skills independent of previously acquired knowledge to solve novel problems. In addition, Au et al. (2015) found that training participants on a working memory task resulted in a significant, positive effect on general intelligence scores. Similar findings have been reported in animal studies. In a preclinical model, Light et al. (2010) reported that in laboratory mice, regular working memory practice improved the animals' aggregate scores on a battery of diverse and complex learning tasks.

Whenever an individual is required to reason through a novel situation, they must preserve multiple goals in working memory while being able to simultaneously handle that information to work toward the intended goal. Thus, increasing working memory ability could have important implications for navigating novel reasoning scenarios. However, results concerning the relationship between working memory training and various measures of cognitive functioning, namely intelligence, have sometimes been mixed (Redick, Shipstead, Harrison, Hicks, Fried, Hambrick & Engle, 2013) and failed to show improvement in universal cognitive functioning (Melby-Lervag & Hulme, 2013) which suggests that working memory and intelligence should not be considered synonymous constructs. Nevertheless, there remains a clear empirical link between working memory faculties and certain cognitive functions such as intelligence and novel problem solving capability. That said, an intervention to improve working memory may result in benefits to cognitive performance in general. As such, attempting to further understand the mechanisms and processes that improve working memory should be a priority.

There has been success in training participants to improve on working memory tasks, and often improvement in these tasks is coupled with improvement on other cognitive tasks (*i.e.,* intelligence tasks, central executive functioning tasks). However, these improvements have been difficult to generalize. With that in mind, there could be more optimal strategies for enhancing working memory capacity in a way that derives more broad and reliable improvements in cognitive ability.

Physical activity and cognition

An in-depth review conducted by Brownson, Boehmer, and Luke (2005) examined changing trends in physical activity in the United States for as many as 50 years. It was found that overall, work-related activity, transportation-related activity, and recreation activity have declined while sedentary activity has increased (Brownson, Boehmer, & Luke, 2005). Other researchers have found similar patterns in physical activity trends (Lakdawalla & Phillipson, 2002; Mirowsky & Ross, 2010, Wyatt & Hecker, 2006). In 2009, physical inactivity was identified as the fourth leading risk factor for non-communicable, chronic diseases and accounted for more than three million preventable deaths (World Health Organization, 2009). According to the World Health Organization, physical inactivity is defined as not meeting either of the following criteria: 30 minutes of moderate-intensity physical activity on at least five days every week or 20 minutes of vigorous-intensity physical activity on at least three days every week.

In spite of the overwhelmingly apparent full-body benefits of physical activity, less is known about the effects of exercise on cognitive functioning and the brain. However, research that has been done in this area strongly suggests that the central nervous system and cerebrovascular system experience diverse physiological benefits as a result of physical activity. Such positive changes include increased cerebral blood flow (Bailey, Marley, Brugniaux, Hodson, New, Ogoh & Ainslie, 2013), increased concentration of growth factors (Cotman, Birchold & Christie, 2007; Gustafsson, Puntschart, Kaijser, Jansson, & Sundberg, 1999) increased concentration of endothelial cells linked to angiogenesis (Laufs, Werner, Link, Endres, Wassmann, Jurgens & Nickenig, 2004), changes in dendrite concentration (Stranahan, Khalil & Gould, 2007), increased brain volume in adults (Colcombe, Erickson, Scalf, Kim, Prakash, McAuley & Kramer, 2006), and even neurogenesis in certain regions of the brain (Bednarczyk, Aumont, Decary, Bergeron & Fernandes, 2009).

A high level of brain performance is essential for cognitive function. The brain accounts for as much as 2.5% of the body's total mass, and requires about 20% of the body's total basal energy use and an average of 15% of the body's total blood flow (Kramer & Erickson, 2007). The neurons in the brain rely on sodium-potassium pumps to maintain electrochemical gradients, and these pumps require adenosine triphosphate, oxygen, and glucose be delivered via blood in the cerebrovascular system. Cardiovascular, respiratory, and metabolic fitness are important in maintaining adequate blood supply to the nervous system (Cotman, Berchtold, & Christie, 2007; Hillman,; Kramer & Erickson, 2007; Erickson, & Kramer, 2008; Spiro & Brady, 2008). Importantly, cerebrovascular networks are considered to have a high degree of plasticity (Churchill et al., 2002). Physical activity, and the resulting improved cardiovascular, respiratory, and metabolic fitness have been shown to encourage the development of new capillaries in the brain (Ainslie et al., 2008; Churchill et al., 2002). With the numerous physiological benefits derived from exercise in mind, we will now turn our attention to aerobic exercise, specifically, and its effects on cognitive functioning.

Aerobic exercise and cognition

Aerobic exercise, as compared to anaerobic exercise, involves stimulating the heart rate continuously by maintaining a challenging but reasonably sustainable level of physical activity throughout an entire workout session. Examples of aerobic exercise include activities like running, biking, swimming, and using cardio machines while examples of anaerobic exercise include activities such as weight lifting or sprinting. Aerobic exercise allows an individual to gradually increase aerobic capacity, thereby increasing maximum capacity as training continues.

Several neuroimaging studies including older adult participants show that higher levels of aerobic fitness are associated with larger volumes of the hippocampus, a region paramount to learning and memory and especially critical to consolidating information from working memory to long term memory (Colcombe et al., 2011; Erickson et al., 2011). Some researchers have attributed these effects to increased cerebrovascular reserve (Brown et al., 2010) while others highlight neurogenesis resulting from aerobic fitness (Burns et al., 2008). Furthermore, a review by Guiney and Machado (2013) indicated beneficial effects of aerobic exercise on many domains of executive functioning in younger and older adults, particularly working memory capacity. Based on the results of these neuroimaging studies, it seems that aerobic exercise could certainly yield improvements in cognitive functioning potentially as a result of previously mentioned positive physiological effects.

Many researchers have investigated the effects of aerobic exercise on cognitive functioning directly by implementing exercise intervention studies. In general, studies of this kind aim to quantify the effects of an exercise intervention by comparing certain criteria that were tested before and after the exercise interventions. For example, researchers implementing a weight-loss exercise intervention would be interested in directly comparing participants' pre-intervention weight and post-intervention weight. Additionally, some intervention studies include a control group that consists of individuals who do not participate in the intervention. Members of the control group can then be compared to the individuals who have undergone the intervention, usually referred to as the intervention group.

One single-blind randomized controlled trial examined the effects of Tai Chi training on future clinical dementia diagnosis at posttest assessment. All participants recruited for the study were at risk of cognitive decline based on Clinical Dementia Rating (CDR). The intervention group participated in Tai Chi training three times a week for at least thirty minutes over a period of twelve months while the control group consisted of stretching and toning classes. The control group was more likely to be diagnosed with clinical dementia (17%) than the intervention group at posttest assessment (4%; Lam et al., 2012).

A randomized controlled study of individuals with mild cognitive impairment examined the effects of a multi-component exercise intervention on cognitive performance. The multi-component exercise intervention consisted of aerobic exercises, strength training, and postural balance training practiced during eighty individual ninety-minute sessions over a twelve-month period, while the control group consisted of various educational classes over the same twelve-month period. The intervention group scores improved on at least half of the cognitive tasks—mini-mental state examination, immediate recall and verbal fluency tasks—while the control group scores did not improve (Suzuki et al., 2012).

The following year, this study was extended with the additional objective of identifying potential biomarkers associated with the connection between aerobic exercise and cognition (Suzuki et al., 2013). One hundred older adults (*M* age = 75) with mild cognitive impairment were recruited to the study and randomized into the intervention group or the control group. Similar to the previous study, the intervention group participated in multi-component exercise which took place two times a week for ninety minutes for a six-month period. Compared to the control group, the intervention group exhibited significantly better Mini-Mental State Examination and logical memory scores. Interestingly, increased levels of brain-derived neurotropic factor and low levels of total cholesterol were significantly related to increased cognitive ability at post-assessment.

A large amount of research investigating the protective effects of exercise interventions on various aspects of cognitive decline has focused on older adults and certain clinical populations. Aging adults may experience cognitive decline, and could potentially benefit from cognitive performance-enhancing physical exercise interventions (Nouchi, Taki, Takeuchi, Sekiguchi, Hashizume, Nozawa, Nouchi, & Kawashima, 2014; Yun & Abrahamson, 2015). Furthermore, cognitive deficits associated with depression (Greer, Grannemann, Chansard, Karim, & Trivedi, 2015) and schizophrenia (Oertel-Knochel, Mehler, Thiel, Steinbrecher, Malchow, Tesky & Hansel, 2014) may improve as a result of increased physical activity. Importantly, very few studies have included healthy young adult participants, as they are generally considered to be at the developmental peak of cognitive functioning.

However, emerging data suggest that regular aerobic exercise may also be beneficial for cognitive functioning in young adults. Aberg et al. (2009) conducted a prospective cohort study including all Swedish men born between 1950 and 1976 who were enlisted for military service at age eighteen. The overall sample included 268,496 full-sibling pairs, 3,147 twin pairs, and 1,432 monozygotic twin pairs. Linear models revealed that cardiovascular fitness, but not muscular strength, was associated with intelligence, and that cardiovascular fitness at age eighteen predicted educational achievements later. In addition, the researchers performed cross-twin, cross-training analysis on monozygotic and dizygotic twin pairs in the sample, finding that the associations were greatly attributable to individual, non-shared environmental characteristics (>80%) over heritability (<15%; Aberg et al., 2009). The twin comparisons show great promise for the malleability of these traits by demonstrating a strong environmental influence on the association between fitness and cognitive performance.

A similar study compared active and sedentary young adults on their performance on a task-switching paradigm including two conditions. The pure task condition required repeated performance on a single task while the mixed-task condition required switching rapidly between tasks, exhibiting greater executive control. The physically active group scored higher on the mixed-task condition as compared to the sedentary group (Kamijo & Takeda, 2010).

Themanson, Pontifex, and Hillman (2008) reported that cardiorespiratory fitness was associated with greater cognitive control in a sample of eighteen to twenty-five year-olds. Participants were classified based on cardiorespiratory fitness level and error-related negativity was recorded to determine task-monitoring ability. The findings suggest that increased fitness could be linked to increased cognitive flexibility. Finally, a review by Guiney and Machado (2014) found consistent links between habitual aerobic exercise and cognitive functioning in healthy adults. One recent study investigated working memory abilities specifically. Padilla, Perez, and Adres (2013) found that high physical activity as compared to sedentary behavior was associated with higher stroop span task and automatic operation span scores in female college students eighteen to thirty years old. The stroop span task and the automatic operation span task variations of a typical digit span task, and are used widely in working memory research.

The relationship between aerobic exercise and working memory in young adults has also been examined experimentally. One study utilized an extremely unique participant pool and design. Participants aged eighteen to twenty-two years old were recruited from the Royal Norwegian Navy. All participants had been trained for a short period of time before half of the Navy recruits were deployed for service and discontinued training (de-trained group) and half of the participants continued training for eight weeks. One aim was to investigate the relationship between physical fitness and cognitive functioning in this young, healthy sample. Computerized versions of two cognitive tasks were used to assess cognitive functioning: a continuous performance task (CPT) and a working memory test (WMT). Importantly, the WMT was developed by Hugdahl et al. (2000) based on Baddeley and Hitch’s (1974) model. Results indicated that the young adults who participated in the eight-week training program scored significantly higher with faster response times on the WMT than the detrained group who remained sedentary throughout the same eight weeks (*Cohen's d* = .31; Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004).

Another study examined the effects of a yoga intervention utilizing both fast and slow pranayama on executive functions in a sample of healthy, young volunteers. Fast pranayama, while not clearly an example of aerobic exercise, involved a similar structure to high intensity interval training (H.I.I.T.) which will be discussed in more detail later. Fast pranayama consisted of four consecutive six-minute cycles, each separated by a one-minute break. These cycles were fast-paced and alternated in technique each subsequent cycle. Slow pranayama consisted of three low intensity nine-minute cycles with less alternating between positions. Though both fast and slow pranayama improved scores on several measures of executive functioning, working memory, measured using the Reverse Digit Span task, was significantly improved only in the fast pranayama group (*Cohen's d* = .39; Sharma, Kumar, Velkumary, Subramanian, Bhavanani, Madanmohan, & Thangavel, 2014). This study provides insight into the subtleties of fitness changes in young adults. While any increased level of physical activity could potentially benefit one's health, these findings suggest that slow pranayama (low intensity) and fast pranayama (high intensity) influenced different measures of working memory in different ways in the sample studied.

High intensity interval training

Recent studies have demonstrated that aerobic high intensity interval training (H.I.T.T.) offers unique benefits over continuous moderate aerobic exercise training.

High intensity interval training was found to be superior to continuous moderate exercise training in lowering blood pressure (Molmen-Hansen et al., 2012). Furthermore, results from several randomized controlled studies indicated that high intensity interval training was superior to continuous moderate exercise in enhancing aerobic capacity (Kessler, Sisson, & Short, 2012; Rognmo, Hetland, Helgerud, Hoff, & Slordahl, 2004; Wisloff et al., 2007). High intensity interval training involves counterbalanced bouts of both high intensity exercise and low intensity exercise. The intensity level is calculated based on an individual's maximum heart rate. Each interval (high or low) has a different heart rate goal; for example, 50-60% maximum heart rate goal during low intensity intervals and >85% maximum heart rate goal during high intensity intervals. In contrast, a continuous moderate exercise session would be more likely to consist of a lower heart rate goal, such as 65%, sustained for the entirety of the session. Overall, aerobic high intensity interval training has been shown to improve physiological aspects of health such as body mass index, blood pressure, heart rate, and maximum oxygen uptake more rapidly than continuous exercise methods (Wisloff et al., 2007). In fact, these positive results can often be observed in as little as six to eight weeks (Bruseghini et al., 2015).

Current Study

Aerobic exercise interventions with the intent of maintaining or improving cognitive performance in aging cohorts and clinical populations are important. Furthermore, improvements in cognitive performance in individuals with mild cognitive impairment, as described above, offer hope for curbing the onset of potential neurodegenerative disorders. However, there is still an apparent gap in the literature. Healthy young adults, unlike aging adults and certain clinical populations, are presumed to be at the peak of cognitive functioning. However, if an average healthy young adult can reap cognitive benefits in addition to physical benefits by adopting a regular aerobic exercise regimen, more empirical attention should be paid to the matter. Furthermore, if regular aerobic exercise promotes improved cognitive functioning, it is possible that living a sedentary lifestyle leaves one vulnerable to suboptimal cognitive functioning. Given the clear benefits of improved cognitive functioning, and the currently increasing rate of sedentary children, teens, and young adults (World Health Organization, 2009), a better understanding of the conditions under which sedentary but otherwise healthy individuals can reap cognitive benefits should be understood. The current study seeks to investigate the possible effects of an eight-week H.I.I.T. aerobic exercise intervention on the working memory performance of sedentary but otherwise healthy college students.

Hypotheses

The proposed research seeks to test several hypotheses about the effects of a H.I.I.T. exercise intervention on working memory:

Hypothesis 1. Working memory performance, as measured by three distinct working memory tasks, will be higher at post-intervention assessment than at pre-intervention assessment. It is expected that working memory task performance will increase following the high intensity interval training exercise intervention.

Hypothesis 1a. Performance on the Psychology Experiment Building Language (PEBL) reverse digit span task will be higher at post-intervention assessment relative to pre-intervention assessment. It is expected that improvements on performance will occur following the H.I.I.T. exercise intervention. Improved performance will be indicated by a larger PEBL reverse digit span (maximum number of digits recalled accurately) at post-intervention assessment. An improved digit span suggests a heightened ability to simultaneously store and manipulate information, a pivotal component of the Baddeley and Hitch (1974) multi-component model of working memory.

Hypothesis 1b. Performance on the PEBL visual-response memory span task will be higher at post-intervention assessment relative to pre-intervention assessment. It is expected that improvements on performance will occur following the high intensity interval training exercise intervention. Improved performance will be indicated by a larger visual span (maximum number of images recalled accurately) at post-intervention assessment. An improved visual span also suggests an enhanced ability to simultaneously store and manipulate information, specifically that of the visuospatial variety, which is also a key component of the Baddeley and Hitch (1974) model of working memory.

Hypothesis 1c. Performance on the PEBL symmetry span task will be higher at post-intervention assessment as compared to pre-intervention assessment. It is expected that improvements on performance will occur following the high intensity interval training exercise intervention. Improved performance will be indicated by a larger letter span (maximum number of letters recalled accurately) at post-intervention assessment. An improved letter span, like the previous span tasks, suggests a heightened ability to simultaneously store and manipulate information. However, since this task is considerably more challenging than a traditional digit span task because of the inclusion of a distracting co-task, improved letter span could suggest more significant improvement in the ability to store and manipulate information.

Chapter 2: Methods

The proposed research was conducted as a component of the P.I.C.E.S. (Pilot Intervention of Culturally-Responsive Exercise System) study, in which the main goal was to quantify improvements in physiologic and cognitive indicators of health in sedentary young adults who participated in a culturally responsive exercise program (See Table 1). The P.I.C.E.S. study is supported by the Maxwell Lutz community impact award, and approved by Northern Arizona University's Institutional Review Board.

Participants

To join the study, participants were required to be healthy but sedentary college students eighteen to thirty-five years old. We defined healthy according to exclusion criteria for the P.I.C.E.S. study protocol, described in more detail below. All participants were non-smokers with a body mass index (BMI) <35 kg/m^2. BMI was calculated based on self-reported height and weight provided during a preliminary phone screen, then verified when height and weight were measured at the first study visit. All participants were also normotensive (blood pressure $\leq$ 140/90 mmHg). Blood pressure was obtained during the first study visit to confirm normotensive status. Participants were categorized as sedentary using the International Physical Activity Questionnaire (IPAQ). If a participant self-reported participation in exercise of any kind more than two times per week, he or she did not qualify as sedentary and was disqualified from participation in the study.

Participants were pre-screened over the telephone to determine eligibility. Identifying information was not recorded until after the pre-screening questionnaire was completed and the individual qualified for the study and remained interested. Thus, information collected during the preliminary screening was only be used to determine eligibility. All participant data were identified by a unique participant identification number.

Recruitment and compensation

Participants were recruited through various Northern Arizona University resources: the SONA system (an online database offering student and faculty researchers the ability to participate in or recruit participants for approved studies), class announcements, IRB approved fliers, and recruitment tables on the university campus (See appendix *B-D*). Recruitment materials were designed to direct interested participants to call Northern Arizona University's Cardiovascular Regulation Laboratory where a trained research assistant in the lab could conduct a preliminary phone screening. Participants may have received class credit for participation, but no monetary compensation was provided.

Informed consent

Participants meeting inclusion criteria were invited to Northern Arizona University's Cardiovascular Regulation Laboratory where a trained researcher obtained informed consent. Obtaining informed consent involved a research assistant providing a thorough description of what was to be asked of the participant throughout the course of the study, an explanation of the risks and benefits of the study, and finally, addressing any questions raised by the participant. In addition, each participant was provided with two copies of the approved consent form. Participants provided informed consent by signing one copy of the informed consent document to be stored in the Cardiovascular Regulation Laboratory keeping one copy for themselves.

Procedure

Informed consent and pre-screening visit

This visit took place at Northern Arizona University's Cardiovascular Regulation Laboratory. A trained research assistant provided the participant with informed consent materials and delivered a detailed explanation of the procedures and expectations of the study as described above. Next, the research assistant obtained medical history, height, weight, resting blood pressure, resting heart rate, and resting 12-lead electrocardiogram. In addition, the International Physical Activity Questionnaire (IPAQ), a validated self-report measure of physical activity, and the Physical Activity Readiness Questionnaire (PARQ) were administered during this visit. Results of these screening measures were examined to exclude noneligible participants. For example, answering 'yes' to the item, "Do you feel pain in your chest during physical exercise?" on the PARQ is disqualifying (See Appendix).

In two separate visits, additional cardiovascular testing was completed (*i.e.,* flow-mediated dilation, cold pressor test, flow-mediated dilation with cold pressor test, and mental stress test) to quantify potential improvements in physiological indicators of health as a part of the broader P.I.C.E.S. study. For more detailed information about the pre-intervention and post-intervention cardiovascular assessment visits, see Appendix.

Working memory and fitness assessment visits

These visits took place at the Health and Learning Center (HLC) at Northern Arizona University in a private testing room once at baseline and once more after completion of the eight-week H.I.I.T. exercise intervention. Three to five trained research assistants from the departments of Psychological and Biological Sciences participated in each session of data collection.

First, participants were asked to complete a total of three working memory tasks on a laptop computer. A trained researcher from the Psychological Sciences department administered the tasks. Additional fitness measures were collected immediately after completion of the working memory tasks. Specifically, pre-intervention weight and body fat percentage were measured. Body fat percentage was measured using the skin caliper method. Lastly, fitness was assessed using a timed 1.5 mile run on the track in the HLC which was recorded in minutes and seconds on a stop watch.

The three cognitive tasks to assess working memory were compiled into a single test battery using the Psychology Experiment Building Language (PEBL), an open source software program which allows researchers to design and implement psychological experiments (Mueller, 2011). A university laptop computer was used to access PEBL version 0.13 and create the test battery used for this study. The working memory tasks used in the test battery include the PEBL reverse digit span task, the PEBL visual-response memory span task, and the PEBL symmetry span task. The three tasks were automatically randomized.

The PEBL reverse digit span task involves storing and processing lists of digits that are presented visually on a screen and spoken through headphones, providing both visual and audio stimuli. Participants were shown a set of digits, presented one at a time on the screen, and instructed to type (recall) the items on the next screen. However, rather than being asked to recall the digits in the order in which they were presented, participants were instructed to recall the digits in reverse order. Recalling a list of digits in the same order as presented merely requires storage ability, while the mental reversal of the digits requires both storage and processing. When participants could successfully recall a list of items in reverse order, the list of digits in the next trial would lengthened by one. This pattern of lengthening digit spans following successful trials continues until the participant is unsuccessful in recalling the list of digits correctly. The task begins with a list length of three digits and the longest possible list length is ten digits. Thus, the participant's digit span was determined using the maximum number of digits that could be recalled accurately, up to a maximum value of ten.

The PEBL visual-response memory span task involved attempting to successfully recall sets of simple images from a bank of a total of nine images. The participant was presented with a set of black and white images, one at a time, on the screen. Each set varied in the number of images it contained (explained below). Next, a bank of nine standard black and white images (apple, bus, deer, pear, tree, bird, chipmunk, fish, and plane) was shown on the screen. The participant was instructed to select (click on) each image that was presented previously in the order in which they were shown. Even though the order of the items is not reversed prior to recall, being forced to select different combinations of images continuously from the same bank of similar images introduces a unique kind of interference. Each time the participant could successfully recall the list of images in the correct order, the set of images in the next trial increased by one image. Similarly, when the participant was unsuccessful, the set of images on the next trial was decreased by one (a staircase effect). However, the staircase feature was limited to one unsuccessful response per set. That said, if the participant is unsuccessful more than once with a particular set (*e.g.*, five images), the task then terminated (rather than producing another trial of five images or increasing to a trial with six images). Thus, the participant's visual-response span was calculated by the maximum number of images successfully recalled, up to a maximum of nine images.

The PEBL symmetry span task is based on an original task created by Daneman and Carpenter (1980), with automated procedures based on protocol outlined by Unsworth et al. (2009). General reading span task procedures are described in a previous section. The PEBL Symmetry span task required participants to engage in one cognitively demanding task while also engaging in a distracting co-task. The initial task involved holding a continually growing set of letters in working memory. Letters appear one at a time on the screen, with a separate distractor sentence appearing between each presented letter. An example of a distractor sentence includes, "I brush my teeth with my cell phone." The participant must select 'true' or 'false' based on the basic logic of the sentence before being presented with a new letter in the set. Thus, the participant was required to maintain the growing set of letters in memory while simultaneously attending to distractor sentences between each new letter. Each time a participant succeeded, an additional letter and sentence would be added to the subsequent set. Thus, reading span was calculated based on the largest set of letters the participant was able to correctly recall in spite of the distractor task (evaluating sentences), up to a maximum of seven letters.

Participants' scores for each task were stored on the same university laptop computer on which the working memory tasks are administered. The protocol described for this visit occurred once more in the same manner at post-intervention assessment.

Exercise classes

Exercise classes were held in a group fitness room at the HLC on the same days (Sunday, Tuesday, and Thursday) each week at the same time (7:00 pm). Each exercise class was approximately one hour in duration and there were twenty-four classes total. The participants were required to attend at least twenty of the twenty-four classes to remain in the study. However, the participants were strongly encouraged to attend one-hundred percent of the classes. Group fitness classes were free of charge to P.I.C.E.S. participants and Northern Arizona University students, though no classes were attended by non-participants.

The exercise sessions consisted of H.I.I.T. cycling workouts timed to the beat of Native American drum music. Upon arrival, participants were fitted with a Polar heart rate monitor on the upper abdomen/lower chest. These heart rate monitors were designed to connect wirelessly to the following: the personal trainer's bike screen, the participant's individual bike screen, and a tablet monitored by a trained research assistant. Throughout each exercise class, the personal trainer and the research assistant collaborated to monitor participants' heart rate data. The goal was for each participant to remain within heart rate targets calculated based on intensity level and the participant's height, weight, and age.

The workout consisted of a five-minute warm up (heart rate at 65-75% of individual calculated maximal heart rate; HR max = 220-age). Warm up was followed by four separate sets of high and low intensity intervals. The high intensity intervals lasted for four minutes each and participants were asked to maintain a heart rate between 85-95% of their calculated maximum. Low intensity intervals lasted three minutes and participants were asked to maintain a heart rate 60-75% of their calculated maximum. Following these four sets was a five-minute cool down at 50-60% of their calculated maximum heart rate. The group fitness class was led by the same trained fitness instructor throughout the duration of the study.

A group cycling class was chosen as the exercise intervention, as research has suggested that one of the most effective methods for executing a physical activity intervention is via group exercise classes (Davis & Reid, 1999). The use of cycling workouts was selected because of the several advantages cycling offers over other aerobic methods such as treadmill exercise. First, cycling is advantageous because it can be performed at a wide range of intensities and speeds (Oja et al., 2011). Second, pedaling on a bike is considered safe for individuals with a variety of fitness levels (Cakit et al., 2010), therefore offering a significantly reduced risk of injury in sedentary populations.

Data analysis

Preliminary data analysis was conducted on a subsample of 6 participants who participated in the first cohort of the P.I.C.E.S. study in Fall 2016. *A priori* power analysis determined that a total of 27 participants would be required to achieve a power of .80 with alpha set at .05 (one-tailed). The a priori power analysis was calculated using a medium effect size achieved by the few extant studies examining the effects of an exercise intervention on working memory performance (Hansen et al. 2004, Sharma et al., 2014). Thus, this study was significantly underpowered. However, the use of a repeated-measures design increases power by eliminating a notable amount of between-subjects variability (Field, 2013).

Prior to data analysis, the data were inspected for adherence to statistical assumptions. Paired-samples *t*-tests have several statistical assumptions including a continuous dependent variable(s) measured at the interval or ratio level, independent observations of the dependent variable(s), and normal distribution of mean differences with no outliers (Field, 2013). Data screening determined that the data contained no missing values and no concerning outliers. Next, variable distributions were inspected for normality. Nearly all variables violated the Kolmogrorov-Smirnov statistic for normality, $p < .05$. However, when using a paired-samples *t*-test, the most important distribution to examine is the distribution of the differences between scores (Field, 2013). Thus, difference scores were calculated and the distribution of the new difference score variables were examined for normality. Still, all but one variable (PEBL reverse digit span) violated the Kolmogorov-Smirnov statistic for normality, $p < .05$.

To test the hypotheses that working memory performance will be higher at post-intervention assessment, paired samples *t*-tests (one-tailed) were used to examine differences between pre-intervention and post-intervention working memory performance. Alpha level was set at .05.

Hypothesis 1a.

To test the hypothesis that maximum span scores on the PEBL reverse digit span task will be higher at post-intervention assessment as compared to pre-intervention assessment, a paired samples *t*-test was used to examine the influence of participation in the intervention on PEBL reverse digit span task performance.

Hypothesis 1b.

To test the hypothesis that mean scores on the PEBL visual-response memory span task will be higher at post-intervention assessment as compared to pre-intervention assessment, a paired samples *t*-test was used to examine the influence of participation in the intervention on PEBL visual-response memory span task performance.

Hypothesis 1c.

To test the hypothesis that mean scores on the PEBL symmetry span task will be higher at post-intervention assessment as compared to pre-intervention assessment, a paired samples *t*-test was used to examine the influence of participation in the intervention on PEBL symmetry span task performance.

Chapter 3: Results

Participants

A total of 28 participants contacted the Cardiovascular Regulation Laboratory expressing interest in joining the P.I.C.E.S. study. Of these 28, seven individuals qualified for the study and were invited to the first study visit. Thus, a total of seven participants provided informed consent, took part in pre-intervention assessments, and began the H.I.I.T. exercise intervention. However, one participant dropped out of the study because of an ongoing scheduling conflict, leaving a total of six participants who completed pre-intervention assessment, participated in the H.I.I.T. exercise intervention, and completed post-intervention assessment.

An attempt was made to recruit a control group made up of individuals who expressed interest in the study but who did not qualify for participation in the H.I.I.T.

exercise intervention. The control group would have completed pre-intervention and post-intervention assessment without participating in the exercise intervention. However, the 21 individuals who were contacted to participate in the control group declined. Thus, the final sample (N = 6) participated in the eight-week H.I.I.T. exercise intervention.

The sample (N = 6) consisted primarily of white (66.7%) females (66.7%) who were all 18 years old when the study began. All participants were students at Northern Arizona University in their first year of college. One of the main selection criteria for participation in the study was a low level of physical activity. Individuals were considered for participation if they self-reported exercise of any kind occurring less than two times per week. Physical activity level was then validated using participants' reported Metabolic Equivalent of Task (MET) score measured by the International Physical Activity Questionnaire (IPAQ). The average physical activity score at pre-intervention screening was 1192.83 METs with a range from low to moderate physical activity levels. Fitness testing revealed an average 1.5 mile time of 16.83 minutes at pre-intervention assessment. Body Mass Index (BMI) was calculated using the formula provided by the Centers for Disease Control and Prevention (BMI = (weight (kg)/height $(m)^2$)). Average reported pre-intervention BMI of participants was 23.64, ranging from 19.37 to 28.16. Actual BMI was calculated using measured heights and weights during the pre-screening visit to confirm that all participants met BMI inclusion requirements ($< 35\ kg/m^2$). Additional participant characteristics are summarized in Table 1.

Physical fitness manipulation check

Three paired samples *t*-tests (one-tailed) were used to confirm an increase in physical fitness after participation in the H.I.I.T. exercise intervention. The three variables examined to quantify improvements in physical fitness in this study were aerobic fitness (minutes to complete 1.5 mile run), resting systolic blood pressure (mmHg), and resting diastolic blood pressure (mmHg). Paired samples *t*-tests revealed that participants showed improvement from pre-intervention to post-intervention in aerobic fitness. Specifically, a significant improvement in minutes to complete a 1.5 mile run was observed from pre-intervention (M = 16.31, SD = 1.87 minutes) to post-intervention (M = 15.42, SD = 1.95 minutes), $t(5)$ = 2.61, p = .02, 95% CI_D [0.01, 1.77]; η^2 = .90. Decreases from pre-intervention (M = 107.6, SD = 9.29 mmHg) to post-intervention (M = 103.6, SD = 7.70 mmHg) resting systolic blood pressure, $t(5)$ = 1.01, p = .17, 95% CI_D [-4.36, 18.36]; η^2 = .14, were not significant. Lastly, decreases from pre-intervention (M = 66.40, SD = 15.63 mmHg) to post-intervention (M = 61.40, SD = 7.33 mmHg) in resting diastolic blood pressure were not significant, $t(5)$ = 1.10, p = .17, 95% CI_D [-4.21, 14.87]; η^2 = .23 (See Table 2 and Table 3).

Working memory performance

Three paired samples *t*-tests (one-tailed) were used to investigate mean differences in three distinct measures of working memory. Raw span sores for each task can be found in Table 5, and Figure 2-4.

H1a

Performance on the PEBL reverse digit span task did not differ from pre-intervention (M = 5.5, SD =.84) to post-intervention (M = 6.0, SD= .90), $t(5)$ = -0.89, p = .21, 95% CI_D

[-1.95, 0.95]; η^2 = .14. Thus, the hypothesis that maximum span scores on the PEBL reverse digit span task will be higher at post-intervention assessment as compared to pre-intervention assessment was not supported.

H1b

Performance on the PEBL visual-response memory span task did not differ from pre-intervention (*M* = 5.16, *SD* = .41) to post-intervention (*M* = 5.33, *SD* = .82), $t(5) = -1.00$, $p = .35$, 95% CI_D [-1.20, 0.87]; η^2 = .03. Thus, the hypothesis that maximum span scores on the PEBL visual-response memory span task will be higher at post-intervention assessment as compared to pre-intervention assessment was not supported.

H1c

Performance on the PEBL symmetry span task did not differ from pre-intervention (*M* = 6.50, *SD* = .84) to post-intervention (*M* = 6.83, *SD*= .41), $t(5) = -.42$, $p = 0.18$, 95% CI_D [-1.20, 0.87]; η^2 = .20. Thus, the hypothesis that maximum span scores on the PEBL symmetry span task will be higher at post-intervention assessment as compared to pre-intervention assessment was not supported.

Chapter 4: Discussion

In this pilot study, working memory performance and aerobic fitness were examined in healthy, sedentary young-adult participants who completed an eight-week H.I.I.T. exercise intervention as part of the P.I.C.E.S. study. This research aimed to contribute to the narrow body of literature concerning the relationship between physical activity and working memory performance in healthy but inactive young adults. Age-related decline in working memory performance is well-documented (Robbins et al., 1998;

Salthouse, 1994; Van der Linden, Beerten, & Pesenti, 1998; Hester, Kinsella, & Ong, 2004). Furthermore, many studies have quantified improvements in working memory abilities in older adults or clinical populations (*e.g.,* Colcombe et al., 2011; Erickson et al., 2011; Guiney & Machado, 2013; Lam et al., 2012). However, very few studies have attempted to understand how physical activity, particularly aerobic physical activity, influences working memory performance in healthy young adults. It was hypothesized that young adults participating in an eight-week H.I.I.T. exercise intervention that were previously sedentary would experience improvements in working memory performance as measured by a maximum span on three working memory tasks. The results from this study reveal that one measure of physical fitness improved from pre-intervention to post-intervention, however there were no significant improvements in maximum span scores for the PEBL reverse digit span task, the PEBL visual-response memory span task, or the PEBL symmetry span task. Thus, none of the three parts of the hypothesis were supported by significant results.

Assessment of working memory using PEBL

The PEBL reverse digit span task involves storing and manipulating lists of digits that are presented visually on a screen and presented audibly through headphones. The shortest list of digits was made up of three numbers, and the task was not set to have a limit on list length. Thus, participants could advance in digit list length as they continued to answer correctly. If an incorrect response is given, the list of digits on the next trial would be decreased by one. After more than one incorrect response, the task ends.

As described above, participants in this study did not improve significantly in maximum span, the dependent variable chosen to hypothesize improvements in working memory performance on the PEBL reverse digit span task. However, other indications of improvement on the PEBL reverse digit span task were observed. In a *post hoc* investigation, results indicated a significant improvement in overall accuracy in the PEBL reverse digit span task from pre-intervention (M = 5.83, SD = .41) to post-intervention (M = 7.0, SD= .89), $t(5)$ = -2.91, p = .034, 95% CI_D [-2.20, -0.13]; η^2 = .63. Overall accuracy was the total number of correct responses across all trials on the PEBL reverse digit span task regardless of the list (span) length. Although accuracy, in this case, does not suggest improvements in working memory performance defined by increases maximum span length, it could indicate improvements in other areas of cognition not considered in the current study. For instance, the neural mechanisms underlying general accuracy in certain cognition tasks may differ from the neural mechanisms underlying the dependent variables examined here (maximum span). Hansen, Johnsen, Sollers, Stenvik, and Thayer (2004) are among the few studies to explore the relationship between physical activity and cognitive abilities experimentally (using a WM task based on the Baddeley and Hitch model) in young, healthy adults who were either sedentary (DT) or trained (TR) for eight-weeks. In this study, the TR group outperformed the DT group significantly on the WM task, particularly in terms of overall accuracy.

The PEBL visual-response memory span task requires that a participant successfully recall sets of images from a bank of nine black and white images in the order in which they were presented. This task is similar to the PEBL reverse digit span task in that each subsequent set of images increases or decreases by one image in response to correct or incorrect answers. However, in addition to relying on image rather than letter span, this task allows for more than one incorrect answer. That is, the length of image sets will continue to decrease in response to continued incorrect answers. Participants did not exhibit significant increases in maximum span, the dependent variable chosen to test the hypothesized improvements in working memory performance on the PEBL visual-response memory task. In addition, participants displayed no significant increase in overall accuracy on the PEBL visual-response memory span task. These findings confirm that aspects of working memory ability measured by the PEBL visual-response memory span task, namely visuospatial working memory, did not improve in response to participation in an eight-week H.I.I.T. exercise intervention.

The PEBL symmetry span task required participants to engage in one cognitively demanding task while also completing a distracting co-task. The initial task involved holding a continually growing set of letters in working memory. Letters appeared one at a time on the screen, with a separate distractor sentence appearing between each presented letter. The distractor task, in short, involved appraising the distractor sentences in terms of “true” or “false” while maintaining the growing list of letters in working memory. Participants in this study did not improve significantly in maximum span, the dependent variable chosen to test the hypothesized improvements in working memory performance on the PEBL symmetry span task.

Throughout the course of this task, participants are presented with exactly two sets of two-letter lists, five sets of three-letter lists, five sets of four-letter lists, five sets of six-letter lists, and five sets of seven-letter lists, totaling to twenty-seven trials. The order of the presentation of the lists was random. Thus, merely reporting the maximum span was problematic for examining potential improvement in this task. Unlike the other WM tasks in this study, the PEBL symmetry task presented participants with five trials of seven-letter lists independent of their performance on other trials. For example, even if participants were unable to complete two-letter or three-letter lists, they would still receive five trials with seven-letter lists (no staircase function). If participants correctly completed all five trials containing seven-letter lists, their session ended and they were not presented with any trials containing lists greater than seven-letters (ceiling effect). The PEBL symmetry span task differed from the two other working memory tasks in that it limited the participants' freedom to improve their score beyond a seven-letter span. That is, each participant was limited to a maximum span of seven or fewer letters.

Implications for multiple working memory assessments

Participants did not exhibit significant improvement in reverse digit span, visual-response memory span, or reading span performance in response to participation in the H.I.I.T. exercise intervention as measured by a maximum span (Table 4). It is important to note that each of the tasks utilized in this study is theoretically tied to one or more aspects of working memory ability. The reverse digit span task was included to simultaneous assess the storing and processing components of Baddeley and Hitch's multi-component model (see Groeger et al., 1999; Lezak et al., 1995), while the visual-response memory span task was included to assess aspects of visuospatial memory in addition to general working memory (Baddeley and Hitch model, 1974). Similarly, many have argued that the symmetry span (*i.e.,* reading span) task relies on reading comprehension and speed at least in part (Daneman & Carpenter, 1980). *Post hoc* tests provided some indication that changes in cognitive task performance following H.I.I.T. exercise interventions may not be limited to the visuospatial sketchpad and central executive domains of the Baddeley and Hitch model (1974).

Strengths of PEBL working memory tasks

While the use of multiple tests of working memory was intended to account for a broad scope of working memory abilities, it is possible that the tasks chosen for this study were not able to capture potential subtle improvements in working memory ability. It is also possible that the method through which the tasks were administered had an impact on working memory performance. The Psychology Experiment Building Language (PEBL) was used to construct a battery of working memory tasks that were administered on a laptop computer.

It should be noted that there are many benefits to administering cognitive tasks on a laptop computer using a program such as PEBL. Using a laptop computer instead of a human researcher eliminates considerable bias from the data collection process. As mentioned, the program automatically randomizes tasks. Furthermore, participants in this study wore headphones and listened to a recorded voice report numbers while they were being presented on the screen. This vastly surpasses the consistency that can be expected from a human researcher reading numbers aloud while administering tasks in person across various participant visits. Another benefit to administering cognitive tasks in this manner is that PEBL automatically exports individual data files and organizes them into folders based on task and designated participant identification number. These data files are not subject to human error in the same way that paper tasks in need of hand-scoring are. Finally, the PEBL data files generated for each participant include a vast amount of information recorded throughout the course of the tasks. For example, information about the stimulus and response for each trial, response times, and accuracy are all measured by PEBL and available to utilize. Such detailed information would be extremely time consuming to keep track of by hand.

While each of these benefits were considered carefully when choosing to use PEBL to design and administer a battery of working memory tasks for this study, the following section describes a variety of limitations associated with using PEBL, particularly these three PEBL tasks, to measure working memory performance.

Limitations of PEBL working memory tasks

Utilizing a computer-based method for assessing working memory such as the software PEBL provides benefits in terms of procedural parsimony, ease of data entry, and increased confidentiality for participants among others. However, computer-based versions are inevitably restricted by program parameters. That is, not every aspect of the tasks within PEBL was subject to change by the researcher. As a result, maximum span scores could not always be compared consistently across tasks.

The PEBL reverse digit span task included a parameter that set a ten-digit maximum or “upper end”. Thus, even if a participant had successfully remembered ten digits, there could be no opportunity to advance to eleven digits. This is likely not concerning to the current study since participants in this sample displayed a mean maximum reverse digit span of 6 at post-intervention assessment and no participant achieved a span of ten.

The PEBL visual-response memory span task included a total of sixteen trials for each participant. The total number of trials was determined by the total number of picture sets that can be presented. While the number of images in each trial was dependent on the success of the previous response (staircase function), each participant was given the same number of opportunities to answer correctly.

The PEBL symmetry span task, as described above, presented participants with exactly two sets of two-letter lists, five sets of three-letter lists, five sets of four-letter lists, five sets of six-letter lists, and five sets of seven-letter lists, totaling to twenty-seven trials throughout the course of the task. In an attempt to better understand potential improvements in performance on this task, a 'count of maximum span' variable was generated.

Overall, maximum span scores could not be compared across each PEBL task in an intuitive manner. In the following section, general study strengths, study limitations, and future directions will be discussed.

Study parameters and future directions

One unique aspect of this study is the strict inclusion of only individuals who were young and healthy but at the same time physically inactive. This is important because unlike many intervention studies (Lam, 2012; Suzuki et al., 2012; Suzuki et al., 2013), the focus was not to determine if an "at risk" group could be returned to a "healthy" state). Rather, the focus was to explore the impact of the adoption of a rigorous physical activity regimen in sedentary but otherwise healthy individuals. Specifically, participants were required to be non-smoking, normotensive, and free of any medical conditions that would prevent them from participating in vigorous exercise. At the same time, participants were only selected if categorized as sedentary. Unfortunately, locating participants who qualified as both generally healthy and sedentary was difficult. The study sample, though small, consisted of only individuals who were confirmed to fit both categories. However, it may not be possible to detect changes in blood pressure in a young, normotensive sample if blood pressure is related to the mechanism for cognitive improvements resulting from aerobic exercise.

Furthermore, few H.I.I.T. studies that confidently confirm participants' adherence to the intervention (intervention fidelity). That is, many interventions are limited by the inability to track real-time heart rate data. In this study, participants were assigned a personal heart rate monitor that was worn during each exercise class used to monitor heart rate throughout each exercise session (measure of intervention fidelity). Specifically, heart rate data were tracked carefully to determine speed and resistance goals to meet heart rate targets. This provides a unique benefit over many other H.I.I.T. intervention studies (Angadi et al., 2015) by allowing the personal trainer and the research assistant to ensure that heart rate targets were achieved for individual at each interval of each exercise class.

While some measures of physical fitness did improve from pre-intervention to post-intervention in the present sample, there were no significant improvements in maximum span scores for the PEBL reverse digit span task, the PEBL visual-response memory span task, or the PEBL symmetry span task. It is important to note that the mean PEBL reverse digit spans in this sample were comparable to cognitively healthy young adults measured for working memory ability in other studies, suggesting that our sample represented typical (non-impaired) cognitive function in this sample (See Table

5; Brehmer, Westerberg, & Bäckman, 2012; Croschere, Dupey, Hilliard, Koehn, & Mayra, 2012). It is possible that our sample was indeed near the peak of cognitive performance and that further improvements may be limited by maximum WM capacity, or that improvements in this sample may be dependent on factors such as greater than eight weeks of intervention or greater physical fitness than was achieved in this study.

One of the main limitations of the current study is the small sample size and resulting low statistical power. *A priori* power analysis determined that a total of 27 participants would be required to achieve a power of .80 with alpha set at .05 (one-tailed), and only six participants took part in the study. A small sample limits the power of this study to detect a difference in working memory performance if one exists (Field, 2013). A *post hoc* analysis to calculate the achieved power of the current study resulted in a power of .28 using the pilot data (N = 6). Furthermore, the degrees of freedom (df = 5) limited the number of statistical tests appropriate for the current analyses.

An attempt was made to recruit a control group made up of individuals who expressed interest in the study but who did not qualify for participation in the H.I.I.T. exercise intervention. The control group would have taken part in pre-intervention assessment and post-intervention assessment only. However, each of the potential control group members (N=21) declined participation. Approval by the Institutional Review Board specified that the control group only be recruited from non-qualifying individuals who were contacted for the P.I.C.E.S. intervention. As such, no additional recruitment efforts were made in the present study beyond contacting previously phone-screened individuals.

The inclusion of a control group would have allowed for the comparison of a cohort that participated in an eight-week H.I.I.T. exercise intervention alongside a cohort that remained sedentary. Data from a similar cohort who did not participate in the H.I.I.T. exercise intervention would have allowed for a stronger interpretation of changes in WM related to the intervention. Thus, future studies utilizing a H.I.I.T. intervention to study working memory performance in young adults should include a sedentary cohort for control.

There is still much to be learned concerning the relationship between H.I.I.T. exercise interventions and working memory, particularly in young adults. In this study, results indicated that while one measure of physical fitness improved from pre-intervention to post-intervention, there were no significant improvements in maximum span scores for the PEBL reverse digit span task, the PEBL visual-response memory span task, or the PEBL symmetry span task.

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List of Appendices

Appendix A: Approved Informed Consent Document

Expiration Date: September 7, 2017 This stamp must be on all consenting documents

Human Subject Informed Consent

Department of Biological Sciences, P.O. Box 5640, Flagstaff, AZ 86011
(928) 523-0883

Title of Study: PICES (Pilot Intervention of Culturally-responsive Exercise System) **Principal Investigator:**

Christopher Frank with Sara Jarvis, PhD as faculty advisor

Dear Participant:

This form is part of an informed consent process for a research study. It will provide information that will help you to decide if you wish to volunteer for this research study. It will help you to understand what the study is about and what will happen in the course of the study.

If you have questions at any time during the research study, you may ask them and should expect to be given answers that you completely understand. After all of your questions have been answered, if you still wish to take part in the study, you will be asked to sign this informed consent form. You will be given a copy of the signed consent form to keep.

Why is this study being done?
The purpose of this study is to evaluate an eight-week aerobic interval workout intervention using an aerobic cycle workout performed to the beat and time of traditional Native American drum music. We seek to: 1) determine the feasibility of conducting a culturally responsive exercise program on a college campus, and 2) measure improvements in physiologic and cognitive indicators of health from participation in a culturally responsive exercise program. Potential improvements in physiologic and cognitive indicators of health will be evaluated in both an

experimental group who does participate in the exercise intervention and a control group who does not participate in the exercise intervention.

How many subjects will participate and how long will the study take? Forty participants, aged 18-35 yrs old, will be recruited for this study.

The time requirement for the study is as follows:

<u>Study Visit 1:</u> Informed Consent and Screening (1 hr)

<u>Study Visit 2:</u> Pre Cognitive Assessment and Fitness Test (30-60 min)

<u>Study Visit 3:</u> Midpoint Cognitive Assessment (5-10 min)

<u>Study Visit 4:</u> Post Cognitive Assessment and Fitness Test (30-60 min)

The total time requirement for each participant will be ~4 hrs over a ~10 week period.

What will happen if I take part in this study?
This study will involve four testing sessions. The following outlines the details of the study:

<u>Study Visit 1: Informed Consent and Screening (1 hr):</u> You will be asked to visit the Cardiovascular Regulation Laboratory (Biological Sciences building, room 128) at Northern Arizona University for a detailed explanation of the study. If you agree to participate in the study, you will be asked to complete the following:

- Medical history
- International Physical Activity Questionnaire (IPAQ): requests information about your physical activity patterns

We will also obtain:

- Height
- Weight
- Resting blood pressure and heart rate
- Resting 12-lead electrocardiogram: measures the electrical activity of your heart by placing sticky patches on your chest

Responses to the medical history and activity questionnaires, as well as the results of these measurements, may exclude your further participation in the research study, even if you met the initial requirements during the pre-screening process. You may refuse to answer any question(s); however, failure to answer questions will exclude you from participation.

Study Visit 2: pre-cognitive assessment and Fitness Test (30-60 min depending on the your fitness level): You will be asked to visit the Health and Learning Center at Northern Arizona University for the pre-cognitive Assessment and Fitness Test. The cognitive testing phase will take place in a private room in the Health and Learning Center and will include the following tests:

Working memory measures: Three working memory tasks will be completed on a laptop computer.

After completion of the cognitive testing you will go to a private room for body fat testing

Body fat testing: body fat percentage will be assessed using the skin caliper method. Lastly, you will complete:

Fitness Test: You will be escorted to the track where you will complete a timed 1.5-mile walk/run while wearing a heart rate monitor. Upon completion of the test, you will be asked to rate your level of perceived exertion on a numerical scale.

Study Visit 3: Midpoint Psychological Assessment (5-10 minutes): Approximately three to five weeks after the initial cognitive assessment, you will be asked to join one of the investigators to perform one of the working memory tasks once again. This visit will coincide with one exercise class. You will be asked to complete the working memory task once immediately before the class begins and once again immediately after the class ends.

Study Visit 4: Post Cognitive Assessment and Fitness Test (30-60 minutes): Approximately eight to ten weeks after the initial cognitive assessment, you will be asked to repeat the “Cognitive Assessment and Fitness Test” visit once more.

Will there be any cost to you to take part in this study?

There is no cost to you for participating in this study. Transportation to and from Northern Arizona University will not be covered or reimbursed. You will be responsible for parking fees on the Northern Arizona University campus, is applicable.

Will you be paid to take part in this study?
You will not receive monetary payment for participating in this study.

Can I stop being in the study?
Participation in this study is voluntary. You may choose not to participate or you may change your mind at any time. Your participation may be involuntarily terminated for failure to attend the required number of study visits.

If you do not want to enter the study or decide to stop participating, your relationship with the study staff and Northern Arizona University will not change, and you may do so without penalty and without loss of benefits to which you are otherwise entitled.

You may also withdraw your consent for the use of data already collected about you, but you must do this in writing to: Sara S. Jarvis, PhD, P.O. Box 5640, Flagstaff AZ 86011. Any data that has already been de-identified without coding (cannot be linked back to you) cannot be withdrawn.

What are the risks and/or discomforts you might experience if you take part in this study? There are no risks associated with obtaining height and weight, or with measuring blood pressure heart rate or heart rhythm. There are also no risks for taking ultrasound images or taking surveys on physical activity levels.

Listed below are the risks for the various parts of this study:

<u>Body fat percentage:</u> There may be some discomfort or mild bruising associated with obtaining the skin fold measurements with the skin fold calipers.

Working memory tasks: The risks to completing these tests are negligible, no greater than the risks associated with everyday activities such as writing or answering a question in class.

1.5-mile walk/run test: There may be some discomfort that comes with the effort of walking/jogging/running 1.5 miles; however, you are free to walk or stop at any time.

Are there any benefits for you (or for others) if you choose to take part in this research study?

To the larger society this project has potential benefits by outlining a model for an exercise intervention that could be adapted for many indigenous cultures. Using drum music to pace the workouts makes this protocol usable for any culture that has drum music. This research could also potentially contribute to the understanding of physiological and cognitive benefits due to exercise interventions of this nature.

What other choices do I have if I do not take part in the study?

You may choose not to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

Expiration Date: September 7, 2017 This stamp must be on all consenting documents

Will my study-related information be kept confidential?

Efforts will be made to keep your personal information in your research record confidential, but total confidentiality cannot be guaranteed. Personal information, such as your name and other identifying information will be promptly removed from data sheets and stored in separate files or folders. This will help ensure that confidentiality be maintained. Study records will be stored in password-protected databases on secure drives at Northern Arizona University that require a log on to access and paper files are kept in locked filing cabinets in the laboratory. Only study personnel directly involved with this project will have access to your information. Personal information will be kept for 3 years following completion of the study and then deleted or shredded. Consent forms will be maintained for a period of five years, then destroyed.

Study results will be presented in a de-identified, aggregated format at academic conferences and in published form.

Your records may be reviewed by the following groups:

- Office for Human Research Protections or other federal, state, or international regulatory agencies
- Northern Arizona University Institutional Review Board

Who can you call if you have any questions?
If you have any questions about taking part in this study or if you feel you may have suffered a research related injury, you can call the Principal Investigator or Faculty Advisor at:

Christopher Frank
Department of Biological Sciences
Northern Arizona University
P.O. Box 5460
Flagstaff, AZ 86011
Cell: (303) 956-9668
Cmf292@nau.edu

Dr. Sara Jarvis
Department of Biological Sciences
Northern Arizona University
P.O. Box 5460
Flagstaff, AZ 86011
Office: (928) 523-0883
Cell: (928) 607-0535
Sara.Jarvis@nau.edu

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Human Subjects Research Protection Program at 928-523-9551 or online at http://nau.edu/Research/Compliance/Human-Research/Welcome/.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact **Dr Sara S. Jarvis.** Northern Arizona University is not able to offer financial compensation or to absorb the costs of medical treatment should you be injured as a result of participating in this research.

An Institutional Review Board responsible for human subject's research at Northern Arizona University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

AGREEMENT TO PARTICIPATE

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form**.**

Subject Name:

Subject Signature:_________________________________ Date:

Signature of Investigator/Individual Obtaining Consent:

To the best of my ability, I have explained and discussed the full contents of the study including all of the information contained in this consent form. All questions of the research subject and those of his/her parent or legal guardian have been accurately answered.

Investigator/Person Obtaining Consent:

Signature:__________________________________ Date:

Appendix B: IRB Approved Recruitment Flier

<u>Do you want to get in shape and be involved in research?</u>

The Departments of Biological Sciences and Psychology at NAU seek participants for P.I.C.E.S - Pilot Intervention of Culturally-responsive Exercise System

We are examining how high intensity interval training performed to Native American drum

music affects your cardiovascular health and cognitive performance

To participate, you must be:

- 18-35 years old
- Generally healthy
- Non-smoking
- Currently exercise less than 2 x per week
- Willing to exercise in a group setting
- Available for 6 study visits
- Available for 24 exercise sessions on T/Th/Sun, 7-8 pm

Contact: Cardiovascular Regulation Lab (928) 523-8629 - CVLab@nau.edu

Appendix C: Class Announcement Script

Class Announcement

We are conducting a research study to test an eight-week aerobic interval exercise program, which has been culturally adapted using Native American drum music. We are testing this program's ability to improve cardiovascular health and neurocognitive function. This is a collaborative study between Dr. Jarvis' Lab in Biology and Dr. Birkett's Lab in Psychology. We are looking for healthy individuals between the ages of 18-35 years old who are currently sedentary. If you meet the criteria for enrollment in the study, you will be asked to participate in six study visits and participate in eight weeks of exercise training three times a week, which will take approximately 34 hours. These classes are from 7 pm to 8 pm on Tuesday, Thursday, and Sunday. If you are interested in participating, or you would like more information, call that Cardiovascular Regulation Lab at (928) 523-8629.

Appendix D: Email Script

P.I.C.E.S. Email Script

If subject emails with interest in study:

Hi ____,

Thank you for your interest in the study! The next step would be to call the lab for a quick phone screen (phone number below). During the phone screen we will give you the details of the study and ask a few questions to see if you further qualify for the study. You will also be able to ask any questions you may have at this time. There is limited time before classes begin so we ask you call us soon. We look forward to hearing from you.

Thanks,

Christopher Frank

Appendix E: International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

(October 2002)

http://www.ipaq.ki.se/ipaq.htm

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of

IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an International Physical Activity Prevalence Study is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). Assessment of Physical Activity: An International Perspective. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous and moderate activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

Yes

No Skip to PART 2: TRANSPORTATION

The next questions are about all the physical activity you did in the last 7 days as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing up stairs as part of your work? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ days per week

No vigorous job-related physical activity Skip to question 4

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?

_____ hours per day

_____ minutes per day

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking.

_____ days per week

No moderate job-related physical activity Skip to question 6

5. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?

_____ hours per day

_____ minutes per day

6. During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work? Please do not count any walking you did to travel to or from work.

_____ days per week

No job-related walking Skip to PART 2: TRANSPORTATION

7. How much time did you usually spend on one of those days walking as part of your work?

_____ hours per day

_____ minutes per day

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the last 7 days, on how many days did you travel in a motor vehicle like a train, bus, car, or tram?

_____ days per week

No traveling in a motor vehicle Skip to question 10

9. How much time did you usually spend on one of those days traveling in a train, bus, car, tram, or other kind of motor vehicle?

_____ hours per day

_____ minutes per day

Now think only about the bicycling and walking you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place?

_____ days per week

No bicycling from place to place Skip to question 12

11. How much time did you usually spend on one of those days to bicycle from place to place?

_____ hours per day

_____ minutes per day

12. During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?

_____ days per week

No walking from place to place Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

13. How much time did you usually spend on one of those days walking from place to place?

_____ hours per day

_____ minutes per day

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, chopping wood, shoveling snow, or digging in the garden or yard?

_____ days per week

No vigorous activity in garden or yard Skip to question 16

15. How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?

_____ hours per day

_____ minutes per day

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?

_____ days per week

No moderate activity in garden or yard Skip to question 18

17. How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?

_____ hours per day

_____ minutes per day

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?

_____ days per week

No moderate activity inside home Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY

19. How much time did you usually spend on one of those days doing moderate physical activities inside your home?

_____ hours per day

_____ minutes per day

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?

_____ days per week

No walking in leisure time Skip to question 22

21. How much time did you usually spend on one of those days walking in your leisure time?

_____ hours per day

_____ minutes per day

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like aerobics, running, fast bicycling, or fast swimming in your leisure time?

_____ days per week

No vigorous activity in leisure time Skip to question 24

23. How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?

_____ hours per day

_____ minutes per day

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time?

_____ days per week

No moderate activity in leisure time Skip to PART 5: TIME SPENT SITTING

25. How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?

_____ hours per day

_____ minutes per day

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the last 7 days, how much time did you usually spend sitting on a weekday?

_____ hours per day

_____ minutes per day

27. During the last 7 days, how much time did you usually spend sitting on a weekend day?

_____ hours per day

_____ minutes per day

This is the end of the questionnaire, thank you for participating.

Appendix F: Medical History Questionnaire

PICES- Pilot Intervention of Culturally-responsive Exercise System

Cardiovascular Regulation Lab

617 S. Beaver St. Flagstaff, AZ 86001 (Rm. 128 in Biological Sciences Bldg. 21)

Medical History Form		
Date:		
Last Name: MI:	First Name:	
Occupation:		Email:
Phone: ( )		
Address:		
DOB: / /	Age:	Gender: M / F

Race: What race do you consider yourself to be? Select ONE of the following:
____ ***American Indian or Alaska Native***. A person having origins in any of the original peoples of North, South, or Central America, and who maintains a tribal affiliation or community attachment.
____ ***Asian.*** A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent, including , for example Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. (Note: Individuals from the Philippine Island have been recorded as Pacific Islanders in the previous data collection strategies.)
____ ***Black or African American***. A person having either origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black" or "African American".
____ ***Native Hawaiian or Pacific Islander***. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific islands.
____ ***White.*** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
____ ***Hispanic***. Of or relating to Spain or to Spanish-speaking countries, esp. those of Latin America.
____ Check ***here if you do not wish to disclose any of or all of the above information.***

Emergency Contact:	
Name: Phone #:	Relationship:
Medications: include over the counter drugs/oral contraceptives/dietary supplements	
Name/Dosage/How often taken:	

Allergies:

Medical History: Please explain any "YES" answers below:	
NO ____ YES ____	high blood pressure
NO ____ YES ____	chest pain / history of heart attack
NO ____ YES ____	extra heart beats or racing
NO ____ YES ____	abnormal electrocardiogram (ECG)
NO ____ YES ____	other heart trouble (e.g. murmur, valve problems)
NO ____ YES ____	high cholesterol
NO ____ YES ____	seizures
NO ____ YES ____	strokes
NO ____ YES ____	fainting spells
NO ____ YES ____	anxiety (diagnosed)
NO ____ YES ____	depression (diagnosed)
NO ____ YES ____	recurrent fatigue
NO ____ YES ____	insomnia
NO ____ YES ____	thyroid problems
NO ____ YES ____	difficulty breathing
NO ____ YES ____	emphysema/ asthma/ chronic bronchitis
NO ____ YES ____	tuberculosis
NO ____ YES ____	chronic infection
NO ____ YES ____	stomach/GI problems
NO ____ YES ____	hepatitis
NO ____ YES ____	bleeding disorders
NO ____ YES ______	clotting disorders/history of blood clots
NO ____ YES ____	kidney/ urinary problems
NO ____ YES ____	arthritis (rheumatoid or osteoarthritis)
NO ____ YES ____	migraine headaches
NO ____ YES ____	vision problems (exclude corrected near/far sightedness)
NO ____ YES ____	surgical procedures
NO ____ YES ____	other

Appendix G: P.I.C.E.S Project Narrative

1) **Investigator**
   Christopher Frank
2) **Protocol Title**
   PICES (Pilot Intervention of Culturally-responsive Exercise system)
3) **Objectives**
   The goal of this pilot study is to implement an eight-week aerobic interval workout intervention using an aerobic cycle workout performed to the beat and time of traditional Native American drum music. We seek to: 1) determine the feasibility of conducting a culturally responsive exercise program on a college campus; and 2) quantify improvements in physiologic and cognitive indicators of health from participation in a culturally responsive exercise program.

   Hypothesis: Participants who complete eight weeks of culturally responsive aerobic interval training three times a week will have improvements cardiovascular health, endothelial function, and cognitive performance.

4) **Background**

In the past 40 years, chronic diseases associated with low physical activity (PA) levels have become the most prevalent cause of early morbidity and death in indigenous populations (Teufel-Shone, Fitzgerald, Teufel-Shone, & Gamber, 2009). Low PA levels, accompanied by poor nutrition and other lifestyle factors, have resulted in high rates of obesity, type II diabetes, and cardiovascular conditions such as hypertension and heart attacks in Native American populations (Dunn et al., 1999).

In response to these findings, federal and state governments, as well as other private institutions, have encouraged researchers to investigate lifestyle interventions tailored to Native American populations (Teufel-Shone et al., 2009; Wilson et al., 2005). The majority of such interventions have been conducted on Native American lands, which can pose unique challenges for researchers and participants such as transportation and research oversight (Teufel-Shone et al., 2009). This also poses multiple challenges such as transportation of equipment onto Native lands, gaining support of the entire community, finding a space to set up the project, and control of data and equipment. In addition, previous studies have focused on interventions for elementary and high school students (Teufel-Shone et al., 2009) and research on the effectiveness on a PA intervention for young adults in a university setting is lacking.

Culturally-responsive lifestyle interventions that reflect the motivations, values, or traditions of Native American communities have been shown to have greater and longer lasting effects than programs that do not include these aspects (Davis et al., 1999a; Davis et al., 1999b). Exercising to music is a very popular method of training, especially among those who have recently been physically inactive (Madison, Paulin, & Aasa, 2013). Additionally, music can improve exercise performance by reducing perceived exertion (Karageorghis & Priest, 2012). Thus, the use of indigenous drum music provides this intervention the necessary cultural adaptation to potentially be more effective than a more traditional exercise program.

Recent studies have found that aerobic interval exercise training is much more effective than continuous moderate exercise training (Molmen-Hansen et al., 2012; Bruseghini et al., 2015; Øivind Rognmoa, 2004; Wisloff et al., 2007). Aerobic interval training has been shown to improve physiologic aspects of health such as body mass index, maximal oxygen uptake, blood pressure, heart rate, and endothelial function in a shorter time than continuous exercise modes (Wisloff et al., 2007). The use of cycling workouts brings further advantages because cycling can be performed at a wide range of intensities and speeds (Oja et al., 2011) and pedaling is safe with a wide range of fitness levels (Cakit et al., 2010). Cycling is also a safe intervention in sedentary populations because of the reduced risk of injury compared to other forms of exercise (treadmill running, for example).

Thus, the goal of this pilot study is to implement an eight-week aerobic interval workout intervention using an aerobic cycle workout performed to the beat and time of traditional Native American drum music. We seek to: 1) determine the feasibility of conducting a culturally responsive exercise program on a college campus; and 2) quantify improvements in physiologic and cognitive indicators of health from participation in a culturally responsive exercise program.

5) Lay Summary (approximately 400 words)

Across the globe there are over 370 million indigenous peoples (United Nations.Department of Economic and Social Affairs, 2009). Among indigenous communities there is a severe discrepancy in health and life expectancy compared to non-ingenious peoples in the same countries (Huffman & Galloway, 2010). These differences can be largely attributed to chronic conditions related to low levels of physical activity (Teufel-Shone et al., 2009). The U.S. Department of Health and Human Services reported that 46% of Native Americans are engaged in little to no physical activity for recreational or health purposes, compared to 38% of non-indigenous peoples (Davis, 1998; Coble & Rhodes, 2006). The lack of physical activity has been linked to a higher prevalence of cardiovascular conditions in Native American communities (Moore et al., 2014). For example, the prevalence of diabetes in Native Americans and Native Alaskan communities is more than four times higher than in non-indigenous communities. In addition, the rates of death from cardiovascular events such as heart attack and stroke are nearly doubled among Native Americans compared to other ethnicities in America (Huffman & Galloway, 2010). Increasing physical activity represents one strategy for improving physical and cognitive health. Aerobic interval training has been shown to improve physiological aspects of health in relatively short time periods (Wisloff et al., 2007). In some studies, results were seen in as little as six weeks (Bruseghini et al., 2015). Additionally, increased physical activity can improve neurocognitive function and memory (Paluska & Schwenk, 2000). Research suggests that one of the most effective methods for implementing a physical activity intervention is through the use of group exercise classes (Davis & Reid, 1999). In addition, previous research in indigenous communities has shown that incorporating relevant cultural aspects into the exercise program increases the intervention's effectiveness. We are interested in testing an eight-week aerobic interval exercise program culturally adapted through the use of Native American drum music to improve cardiovascular and cognitive health.

6) Setting of the Human Research

The majority of research will be done in the Cardiovascular Regulation Lab (rm#128) located in the Biology Building (#21) at Northern Arizona University.

The exercise sessions, as well as some of the cognitive testing for this study, will be completed in the Health and Learning Center at Northern Arizona University. A private room will be used for the psychological testing.

7) Resources available to conduct the Human Research

The faculty advisors, graduate students, and undergraduate students from the Jarvis and Birkett Labs will be available to assist with recruitment, obtaining informed consent, data collection during study visits, and analyzing data. These students are required to complete the following training: CITI (IRB), bloodborne pathogens, CPR and AED, and chemical hygiene. The lab is equipped with an AED device in case of an emergency and standard operating procedures are clearly outlined. The lab is also equipped with all of the equipment needed to complete the research including: an electrocardiogram for heart rate monitoring, finger photoplethysmography (Finometer) for beat-by-beat arterial pressure, electrosphygmomanometry (SunTech Tango) for brachial blood pressure, and an ultrasound machine (Acuson Sequoia c256) for imaging arteries. The heart rate monitors for exercise monitoring will be purchased with the grant funds (Polar H7).

The Health and Learning Center at Northern Arizona University will be providing the necessary equipment for the exercise classes, as well as the trainer for this project. This student trainer will be certified in group fitness classes and experienced in coaching on cycling classes.

A computer and software for assessing cognitive performance will be provided by the Birkett lab.

8) Study Population

a) Inclusion and Exclusion Criteria

A total of 40 healthy men and women will be recruited for this proposed study.

- 18-35 yrs old
- Body mass index (BMI) <35 kg/m^2. BMI higher than this is classified as severely obese. BMI will initially be determined by self-reported height and weight during phone screen. Actual height and weight will be measured at screening to verify BMI.

- Normotensive. Hypertension will be defined as blood pressure >140/90 mmHg. These individuals will be excluded as they are not considered generally healthy. Blood pressure will be obtained during screening to verify normotensive status.
- Non-smoking

The following responses on the pre-screening questionnaire will lead to participant <u>exclusion</u>:

- Are you able to attend exercise classes three times a week on Tuesday/Thursday/Sunday from 7-8pm for eight weeks? No
- Are you willing to exercise in a group fitness class? *No*
- Are you exercising less than two times per week? *No. This study is designed for previously sedentary individuals; therefore, those currently exercising should be excluded.*
- Have you used any nicotine products within the last two years? *Yes. Nicotine exposure will influence heart rate and blood pressure; therefore, we would exclude these individuals.*
- Have you lived with a smoker in the last two years? *Yes. Nicotine exposure, even second hand exposure, will influence heart rate and blood pressure; therefore, we would exclude these individuals.*
- In the past year on average how many alcoholic drinks do you have per week? *Disqualify if >14/week as the individual would be classified as moderate/heavy drinker which could influence blood pressure and endothelial function.*
- Have you donated blood or plasma in the last two months? *Yes. A "yes" would exclude the participant because the loss of blood volume will effect blood pressure.*
- Has your father or brother experienced a heart attack or sudden cardiac death before the age of 55 yrs of age? *Yes. A "yes" would indicate more than low risk for participation.*
- Has your mother or sister experienced a heart attack or sudden cardiac death before the age of 65 yrs of age? *Yes. A "yes" would indicate more than low risk for participation.*
- Are you taking any prescription or over the counter medications, prescription medications, or supplements? *Certain medications, surgeries or past injuries will disqualify the participant. Medications that can effect blood pressure and heart rate will exclude participation—these typically would be sleep aids, anti-hypertensives, and herbal supplements but may also include other medications. This will be evaluated on a case-by-case basis.*
- Do you have any medical conditions (example: diabetes, high blood pressure, neurological disease, kidney disease, sleep apnea, depression, history of blood clots, clotting disorders)? *These conditions can affect heart rate, blood pressure, and/or mental status. Some of these conditions (fainting, blood clots) can make exercise dangerous and procedures such*

as the cuff occlusion with the flow-mediated vasodilation are contraindicated for those with blood clots.

- Prior surgeries/injuries will need to be assessed to determine whether: 1) the participant can comfortably lie on the table during testing, and 2) complete the exercise classes.
- Are you pregnant? *Yes. While exercise is not unsafe during pregnancy, there are rapid changes in body composition that would make it difficult to interpret our results.*
- Are you currently breastfeeding or lactating? *Yes. With lactation there are hormonal changes that may influence our data; therefore, we wish to exclude these individuals.*

The following responses on the Physical Activity Readiness Questionnaire (PARQ) (part of pre-screening) will lead to participant <u>exclusion</u>:

- Has your doctor ever said that you have a heart condition or that you should participate in physical activity <u>only</u> as recommended by a doctor? Yes
- Do you feel pain in your chest during physical activity? Yes
- In the past month, have you had chest pain when you were not doing physical activity? Yes
- Do you lose your balance from dizziness? Yes
- Do you ever lose consciousness? Yes
- Do you have a bone or joint problem that could be made worse by a change in your physical activity? Yes
- Is your doctor currently prescribing drugs for your blood pressure or a heart condition? Yes
- Do you know of any reason you should not participate in physical activity? Yes

The American College of Sports Medicine recommends that an individual that answers "yes" to any of these questions should seek physician consultation before beginning an exercise program.

b) Vulnerable populations

n/A

9) Recruitment Methods and Consenting Process

a) Recruitment Process:

Participants will be recruited from the Northern Arizona University campus. We will: 1) distribute flyers around campus, 2) list the study on the Psychology Department's research participation system [(SONA); a mock up of what the potential participant will see is attached to the revised application.], 3) list the study as a group fitness class for students, and 4) set up a recruitment table in high traffic areas on campus to distribute the approved flyers. Interested individuals will be screened over the phone with the pre-screening questionnaires. The Principal Investigator or other qualified lab personnel will evaluate whether participants are qualified. The telephone pre-screening questionnaires will be immediately terminated if the potential participant’s response excludes them from participation.

b) Informed Consent:

Participants will be initially pre-screened over the telephone. Identifying information will not be recorded until after the pre-screening questionnaire is filled out and the individual qualifies for the study and is interested in participation. If the individual does not qualify, records from the pre-screening questionnaire will be immediately destroyed without the identifying information. Information collected during the pre-screen will only be used to determine eligibility. Interested participants who have qualified will be invited to the Laboratory where we will provide an explanation of the risks and benefits of the study and all questions raised by the participant will be addressed. If the participant remains interested, he/she will be provided with two copies the approved consent form. Participants will provide written informed consent through signing a copy of the informed consent document that will be stored in the lab. The second copy will be theirs to keep.

10) Procedures involved in the Human Research

This study will involve six testing sessions and 24 exercise classes. In order to accommodate the participant’s schedule they need to attend a minimum of 20 of the 24 classes during the eight-week period.

<u>Study Visit 1: Informed Consent and Screening (1 hr):</u>

The participant will be asked to visit Northern Arizona University’s Cardiovascular Regulation Laboratory (Biological Sciences building, room 128) for a detailed explanation of the study. If he/she agrees to participate in the study we will obtain informed consent and then he/she will be asked to complete the following:

- Medical history
- International Physical Activity Questionnaire (IPAQ): requests information about their physical activity patterns

We will also obtain:

- Height
- Weight
- Resting blood pressure and heart rate
- Resting 12-lead electrocardiogram: measures the electrical activity of their heart by placing sticky patches on their chest

Responses to the medical history, activity questionnaires, and results from these measurements may exclude the participant from further participation in the research study, even if they met the initial requirements during the pre-screening process. Participants may refuse to answer any questions; however, failure to answer questions will exclude participation. The Principal Investigator or other lab members will be obtaining the informed consent and performing the screening visit.

The order of visits 2 and 3—**Pre Cognitive Assessment and Fitness Test vs Pre Cardiovascular Assessment Visit**—can be interchanged for participants to accommodate scheduling for both the participant and the lab.

<u>Study Visit 2 or 3: Pre Cognitive Assessment and Fitness Test (30-60 min depending on the participant's fitness level)</u>
The participant will be asked to visit the Health and Learning Center at Northern Arizona University for the Pre Cognitive Assessment and Fitness Test. The cognitive testing phase will take place in a private room in the Health and Learning Center and will include the following two tests:
Digit Span Test: The participant will be shown a set of numbers, will be asked to write them down, and then recall the numbers first in the order shown and then with a different number set in reverse.
Letter Set Test: The participant will be shown three sets of letters and asked to say them out loud and then recall what letter was present in all three sets
After completion of the cognitive testing subjects will go to a private room for body fat testing
Body fat testing: body fat percentage will be assessed using the skin caliper method.
Lastly, the participant will complete:
Fitness Test: Participants will be escorted to the track where they will complete a timed 1.5 mile walk/run while wearing a heart rate monitor. Upon completion of the test, the participant will be asked to rate their level of perceived exertion on the Borg scale.

<u>Study Visit 2 or 3: Pre Cardiovascular Assessment Visit (3 hours):</u>
Participants will go to the Cardiovascular Regulation Laboratory at Northern Arizona University, located in the Biological Sciences bldg. (room 128). Prior to the study visit, participants will be asked to refrain from the following activities:

- **72 hours before appointment:** Stop any vitamin supplementation.
- **48 hours before appointment:** No caffeine and alcohol use.
- **12 hours before appointment:** No moderate to vigorous physical activity.
- **4 hours before appointment:** No food or drink other than water.

We will connect the monitoring equipment for the cardiovascular assessment testing. This will consist of sticky patches on the chest for measurement of heart rate and rhythm, a blood pressure cuff around one of the fingers, a blood pressure cuff around the upper arm, and a blood pressure cuff around the lower leg (calf). We will then have the subject lie prone (on their stomach) for the testing. The participant will then complete the following four tests (described in more detail below):

<u>1. Flow mediated dilation (FMD):</u> Ultrasound will be used to locate a blood vessel behind the knee and measure how big the artery is (artery diameter) and how fast the blood is traveling (blood velocity) through the blood vessel. Blood pressure, heart rate, vessel size and blood flow will be measured throughout the duration of the test. After baseline measurements are taken, a blood pressure cuff will be inflated to 250 mmHg around the calf, which will feel very tight. This cuff will stay inflated for 5 minutes and will temporarily block circulation to the lower leg. After the cuff is deflated, we will

continue to collect data for 5 minutes. The release of the cuff will cause the blood vessel to increase in diameter (FMD). We will continue to image the vessel during the recovery phase. There will be 10 minutes of rest before the next test.

Baseline (1 min)	Cuff inflated around calf (5 min)	Recovery (5 min)
← Blood pressure, heart rate, and blood vessel measurements →		

2. <u>Cold pressor test (CPT):</u> Ultrasound will be used to locate a blood vessel behind the knee and measure how big the artery is (artery diameter) and how fast the blood is traveling (blood velocity) through the blood vessel. Blood pressure, heart rate, artery diameter and blood velocity will be measured throughout the duration of the test. We will collect 1 minute of baseline data. After the baseline, we will cover the right hand with two bags filled with an ice water slurry (2-4° C) for 3 minutes. At the end of the 3 minutes, we will remove the ice bags and continue to collect recovery data for 3 minutes. There will be 10 minutes of rest before the next test.

Baseline (1 min)	Cold pressor test (3 min)	Recovery (3 min)
← Blood pressure, heart rate, and vessel measurements →		

3. <u>Flow Mediated Dilation with Cold Pressor Test (FMD + CPT):</u> FMD will be the same procedure as above, but during the last 1.5 minutes of the cuff inflation, we will place a bag of ice and water beneath their hand and a second bag of ice and water on top of their hand for 3 minutes. At the end of the cold pressor test we will remove the ice bags and continue to collect recovery information for 5 minutes. The same measurements as FMD will be recorded throughout this procedure.

	Ice water on hand (3 min)	
Baseline (1 min)	Cuff inflated around calf (5 min)	Recovery (5 min)

← Blood pressure, heart rate, and vessel measurements →

Tests 1-3 (FMD, CPT, FMD+CPT) will be performed in randomized order.

4. Mental stress test (MST): For this test the participant will lie supine on the table and will view a computer monitor above them. There will be a five minute baseline before we begin the test. The monitor will display a two or three digit number and the participant will be told to verbally perform serial subtraction by 6 or 7 from this number. Every 5-10 sec a new number will be given and the participant will be encouraged to give as many answers as they can, as quickly as possible. The mental stress test will be followed by a three-minute recovery.

Baseline (5 min)	Mental arithmetic test (3 minutes)	Recovery (3 min)
← Blood pressure and heart rate →		

Exercise sessions (1 hour each, 24 sessions): Participants will go to the Health and Learning Center for group workout classes, which will take place three times a week over an eight week period. Participants will be required to attend at least 20 sessions during their assigned eight week time period.

The exercise sessions for this study will consist of high intensity aerobic interval cycling workouts, timed to the beat of Native American drum music. Each participant will wear a heart rate monitor for the duration of the class and will have his/her heart rate tracked carefully as the speed and resistance in which they cycle will be determined by their heart rate. The workout consists of a 5 minute warm up (heart rate at 65-75% of their calculated maximal heart rate; HR max = 220-age). Warm up will be followed by 4 sets of high and low intensity intervals. The high intensity intervals will last for 4 minutes each and participants will be asked to maintain a heart rate between 85-95% of their maximum. Low intensity intervals will last 3 minutes and participants will be asked to maintain a heart rate 60-75% of the maximum. After this has been repeated 4 times, there will be a 5 minute cool down at 50-60% maximal heart rate.

Warm up (5 minutes)	Interval sets 4× High intensity (4 minutes) Low intensity (3 minutes)	Cool down (5 minutes)
← Heart rate →		

Study Visit 4: Midpoint Cognitive Assessment (20-30 minutes): immediately following a participant's exercise session between the 10^{th} and 16^{th} class, participants will be asked to sit with one of the investigators to perform the Digit Span Test and Letter Set Test.

The order of visits 5 and 6— **Post Cognitive Assessment and Fitness Test vs Post Cardiovascular Assessment Visit** —can be interchanged for participants to accommodate scheduling for both the participant and the lab.

Study Visit 5 or 6: Post Cognitive Assessment and Fitness Test (20-60 minutes): within one week of completing the required exercise classes, participants will repeat the "Cognitive Assessment and Fitness Test".
Study Visit 5 or 6: Post Cardiovascular Assessment Visit (3 hours): within one week of completing the required exercise classes, participants will be asked to go to the Cardiovascular Regulation Lab for a repeat of the "Cardiovascular Assessment Visit".

Post Study Survey: Three weeks after completing the study, we will call the participant to complete the International Physical Activity Questionnaire (IPAQ)—the same physical activity questionnaire they filled out during screening.

3. **Cost to participants**
   There is no cost to the participant.

4. **Risk to participants**
   There are no risks associated with obtaining height, weight, heart rate/rhythm, or blood pressure. There are also no risks associated with obtaining ultrasound images or completing surveys on physical activity levels.

   Listed below are potential risks involved with this study:
   Body fat percentage: There may be some discomfort or mild bruising associated with obtaining the skin fold measurements with the skin fold calipers.

   Digit span/ letter set tests: The risks to completing these tests are negligible, no greater than the risks associated with everyday activities such as writing or answering a question in class.

   Cold pressor test: By design this test is made to cause short term discomfort (numbness, tingling, pins and needles, and pain in the hand) in order to temporarily increase blood pressure. Once the test is complete, the discomfort will go away quickly and blood pressure will return to normal level. This test does not have any long-term side effects.

<u>Flow mediated dilation:</u> This discomfort from the flow mediated dilation test can include pain, pressure, aching, tingling, or numbness in the lower part of your leg during the cuff occlusion. This discomfort should go away quickly once the test is complete. Individuals with a history of blood clots will be excluded from participation to minimize risk.

<u>1.5 mile walk/run test:</u> There may be some discomfort that comes with the effort of walking/jogging/running 1.5 miles; however, participants are free to walk or stop at any time. Individuals that are high risk for adverse events should be screened out of the study during the pre-screen and medical history review. These tests will always be supervised by someone trained in CPR and AED use should an emergency arise.

<u>Exercise classes:</u> The classes in this study consist of high intensity aerobic interval training on an exercise bike. With such high intensity training there may be discomfort from fatigue and intense effort. Individuals that are high risk for adverse events should be screened out of the study during the pre-screen and medical history review. However, to minimize additional risk, the classes are taught by a certified trainer and a member of the lab staff who will be trained in CPR and AED use will be present during the classes.

<u>Mental stress test</u> is made to cause temporary anxiety in order to temporarily increase your blood pressure. Once the test is complete, the participant's blood pressure will return to normal levels. This test may cause embarrassment but should not have any long-term effects.

5. Potential benefits to participants and/or society

Participants in this study will receive up to 24 free fitness classes and potentially could experience significant improvements in multiple aspects of mental and physical health, including but not limited to improved body composition, reduction of resting blood pressure, improved fitness level, and improved memory and neurocognitive function.

To the larger society this project also has potential benefits in that this study outlines a model for an exercise intervention that could be adapted for many indigenous cultures. Using drum music to pace the workouts makes this protocol usable for any culture that has drum music.

6. Provisions to protect the privacy of participants and the confidentiality of data

a. **Protection of participant privacy:**

During the recruitment process, potential participants will email the Laboratory email address or call the lab to go through the pre-screening questionnaires. Only lab personnel have access to the lab and will be answering those emails and calls. Participant privacy will be assured by placing a sign on the laboratory door during the informed consent and study visits that states: “STOP! Do not enter! Experiment in Progress.” Participant names will not appear on documents associated with the study aside from the signed informed consent documents. Signed informed consent documents will be securely stored in the lab, separate from any data.

b. **Protection of data confidentiality:**
Identifiable data will be stored separately from de-identified data. We will have the following files/folders for each participants (all stored and locked separately): 1) electronic participant tracking file to assign participant ID numbers (identifiable data/contact information); 2) paper folder with contact information page from pre-screening, consent form, and contact/demographic page from medical history questionnaire; 3) paper folder with de-identified data from pre-screening (when applicable), medical history, physical activity, and study visit data; and 4) electronic database with study visit data and cognitive testing data (de-identified).

We will only collect identifiable information on the pre-screening questionnaire if the individual qualifies for the study and expresses interest. We will record this contact information on a separate page from the questions in the pre-screen questionnaire. We will then assign a participant ID number to the potential participant following pre-screening via an electronic password-locked participant tracking file, and mark the code on the questions themselves. This electronic file will be saved on a secure drive that NAU manages which requires a log on to access the files. Each semester, ITS is given a list of people with permission to access this drive. Therefore, only members of the current research team can access these files. The contact page and health questions page from the pre-screening will be stored in two separate paper folders that are kept in separate locked filing cabinets in the laboratory, which is locked during nonbusiness hours.

During the screening visit (visit 1) the consent form and the first page of the medical history form will contain identifiable and demographic data. Those sheets will be stored in the paper folder with the identifiable data. The other pages of the medical history form, and physical activity form, will only contain the participant ID number and will be stored in the de-identified paper folder.

During the study visits data will be collected and written in the folder as de-identified data. Only the participant ID number will be used during data collection.

During the exercise classes participants will each be given a number corresponding to their heart rate monitors when it becomes necessary to ask a participant to increase their pace as their heart rate is not at the required level the number will be called out to avoid identification.

After the data are analyzed, they will be transferred into an excel database on the lab computer. This database will also be password-protected and saved on the secure drive separate from the tracking file. This database will not contain any identifiable information and will only have the individuals ID number. We will retain the data for 5 years upon completion of the study, after which files on the computer with identifiable information will be deleted and paper charts will be shredded.

7. **Participant compensation**
   There is no monetary compensation; however, the participants will receive eight weeks of free
   exercise training and a physical fitness assessment.

8. **Withdrawal of participants**
   Participants will be withdrawn from the study if pre-screening reveals any underlying condition that would make it unsafe to exercise. Participants will also be removed from the study if they miss >4 exercise sessions. Participants may also voluntarily withdraw at any time.

Appendix H: Maxwell-Lutz Community Impact Award Application

Maxwell-Lutz Community Impact Award

1. General team information

Name of Lead Researcher
Christopher Frank
College of Major
CEFNS
Major and student class year while in project
Exercise Science, junior
Contact Address
P.O. Box 5640 Flagstaff, AZ
State/Province
AZ
ZIP/Postal Code
86011
Email Address
Lab email CVLab@nau.edu, personal email – cmf292@nau.edu
Phone Number
Lab phone – 928-523-8629, personal phone- 303-956-9668

2. The Project must effectively integrate at least two of the following categories. Please indicate which of the following categories will be addressed in your project.

Improving health and wellbeing of local and/or global communities
Improve the health and well-being of individual students at Northern Arizona University by creating a culturally-responsive (Native American-based) exercise intervention that can be used in other university settings to support overall health and fitness of all students, including Native American students.

Improving the vitality of community or cultural systems
Improve the vitality and the cultural systems of the community by developing and providing a culturally-responsive (Native American-based) exercise intervention.

Improving environmental sustainability
N.A.

3. Please list the members of your team and college they represent.

Lead Researcher and college
Christopher Frank, CEFNS
Researcher and college
Annalee Boyle, CEFNS
Researcher and college

Jeff Morrison, CEFNS
Researcher and college
Ashley Averett, SBS
Researcher and college
Anna Harris, SBS

4. Please indicate the name or names of faculty assisting you in this project

Dr. Sara Jarvis (CEFNS), Dr. Melissa Birkett (SBS)

5. Please indicate contact information for the faculty endorsers (email and phone)

Dr. Sara Jarvis - Sara.Jarvis@nau.edu, 928-523-0883
Dr. Melissa Birkett - Melissa.Birkett@nau.edu, 928-523-0118

6. Describe the local or global community impact project (200 words or less)

The goal of the project is to serve as a pilot program to assess the health improvements of a culturally-responsive (Native American-based) exercise intervention for all university students, including Native American students. The eight-week aerobic workout intervention focuses on using an aerobic cycle workout preformed to the beat and time of traditional native drum music to improve on a number of aspects of physical and mental health. The physiological elements that the intervention will try to enhance include: reduction of resting heart rate and blood pressure, improved body fat percentage, improved vascular responses to stimulus and increased levels of aerobic fitness. The intervention will also promote aspects of mental health such as an improvement in mood, self-compassion, neuro-cognitive function and memory. Should this intervention prove effective, it could serve as a model for culturally-responsive exercise interventions around the country.

7. List the three (3) major goals of this project.

-Develop a culturally-responsive (Native American-based) exercise program for university students.

-Implement this program as an eight-week, three times a week protocol for the students on the NAU campus to improve both physical and psychological parameters of health.

-Assess the effectiveness of the intervention to create long-term life style changes.

8. Describe intended substantial and verifiable benefit for the community served and student participants (100 words or less)

This intervention will serve to promote physical and mental health aspects for students at Northern Arizona University. Such aspects will include improved fitness parameters such as aerobic capacity and body fat percentage. There will also be cardiovascular improvements such as reduced resting heart rate and blood pressure values, and improved vascular responses to stimulus. The intervention will also target improvements of psychological health including self-compassion, mood, neurocognitive function, and memory. Should this model of culturally adapted exercise intervention prove effective, it can be employed to improve the overall health and well-being in Native American populations around the nation.

9. What is the duration of the project and location?

This project will take place on the Northern Arizona University campus over a two-semester period. The time commitment for each subject will be 30 to 32 hours. This is broken down into several visits. After recruitment, participants will go through an initial informed consent and screening visit (30 min to 1 hr). After this, participants complete the baseline testing (2-3 hrs), which will include assessing physiological responses to stimuli including a cold pressor test and mental stress test. Flow mediated vasodilation will also be assessed to determine “health” of the blood vessels. This phase will also consist of: psychological testing, a positive and negative affect scale to measure mood state, a self-compassion scale, neuro-cognitive function and functional memory tests that will be administered on a computer. Lastly, on a separate visit (30 min), participants will go to the Health and Learning Center (HLC) for initial fitness testing to determine baseline aerobic fitness via a 1.5 mile walk/run. Once 7-10 participants have been recruited we will begin the exercise classes. These classes will be offered three times a week over a two-semester period in the HLC and will last 1 hour each. Participants will be added to the classes in a continuous flow, resulting in individualized starting and ending points. Participants who have signed up for these classes will be expected to attend at least 20 of the 24 assigned classes over an eight-week period. Should a participant miss more than the 4 allotted appointments they will have one week to attend makeup classes. After completing the intervention participants will attend another round of fitness testing at the HLC (30 min) and a repeat of the baseline measurements (2-3 hours). Finally, one month after participants have finished testing, they will be emailed a follow up survey to assess if the workout habits and psychological health improvements have stayed with the participants.

10. Please provide estimated general budget outline for the project.
Budget

Budget

Requested Material	**Estimated Price**
Paper	$30
Color copies for flyers	$50
Toner	$60
File folders	$15
Large blood pressure cuff (2x)	$110
ECG electrodes	$115
Alcohol swabs	$20
Ultrasound gel	$45

Polar H7 heart rate sensor (22x + tax)	$1,857 ($80 each + tax)
Skin fold test caliper x4 for body fat percentage	$120 ($30 each)
ECG paper	$50
IPad for remote collection of HR monitor data & administration of questionnaires	$550
Compensation for group fitness instructor	$1200
Initial predicted funding -	**$4222**

List of Tables

Table 1.

Descriptive fitness and health assessment statistics at pre-assessment and post-assessment

	Pre-assessment *M* (*SD*)	95% CI of *M*	Post-assessment *M* (*SD*)	95% CI of *M*
Total # of classes attended (out of 24)	22.17 (2.17)	[20.62-23.71]		
Height (M)	1.63 (0.06)	[1.58-1.69]		
Weight (Kg)	62.80 (7.20)	[55.21-70.38]	62.48 (7.20)	[54.93-70.04]
Body Mass Index	23.64 (3.07)	[20.42-26.86]	23.33 (2.53)	[20.67-25.99]
Body Fat Percentage (%)	25.27 (7.13)	[17.77-32.76]	20.77 (6.44)	[14.01-27.53]
Resting Heart Rate	82.83 (15.94)	[66.10-99.56]	76.83 (11.30)	[64.97-88.70]
METs (minutes/week)	1192.83 (631.91)	[529.68-1855.98]	1598.50 (1083.80)	[461.12-2735.88]

Table 2.

Summary of fitness measures using paired-samples t-tests (one-tailed)

Fitness measures	Pre-assessment *M* (*SD*)	Post-assessment *M* (*SD*)	*p*	*t*	*d*
Timed 1.5 mile run (minutes)	16.31 (1.87)	15.42 (1.95)	0.02*	2.61	0.47
Resting systolic blood pressure (mmHg)	107.6 (9.29)	103.6 (7.70)	0.19	1.01	0.47
Resting diastolic blood pressure (mmHg)	66.40 (15.63)	61.40 (7.33)	0.17	1.10	0.41

* $p < .05$ (one-tailed)

Table 3.

Descriptive statistics for aerobic fitness measures

	Timed 1.5 mile run (in minutes)		**Resting Systolic Blood Pressure (mmHg)**		**Resting Diastolic Blood Pressure (mmHg)**	
Participant #	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
2	15.13	15.13	112.0	90.00	63.00	56.00
3	15.93	13.67	102.0	90.00	64.00	63.00
4	13.37	12.67	97.00	106.0	56.00	56.00
5	17.50	17.42	105.0	106.0	65.00	66.00
6	17.50	16.37	120.0	109.0	93.00	70.00
7	18.43	17.25	114.0	107.0	54.00	52.00

Table 4.

Summary of performance on three working memory tasks using paired-samples t-tests (one-tailed)

Task	Pre-assessment *M* (*SD*)	Post-assessment *M* (*SD*)	*t*	*p*	*d*
PEBL reverse digit span	5.50 (0.84)	6.00 (0.89)	-0.89	0.21	0.58
PEBL visual-response memory span	6.50 (0.84)	6.83 (0.41)	-1.00	0.18	0.32
PEBL symmetry span	5.12 (0.41)	5.33 (0.82)	-0.42	0.35	0.50

** $p < .05$ (one-tailed)

Table 5.

Maximum correct span on three PEBL working memory tasks

	PEBL Reverse Digit Span Task		**PEBL Symmetry Span Task**		**PEBL Visual-Response Memory Span Task**	
Participant #	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
2	5.0	6.0	7.0	7.0	5.0	5.0
3	7.0	6.0	7.0	7.0	6.0	5.0
4	6.0	5.0	7.0	7.0	5.0	7.0
5	5.0	6.0	5.0	7.0	5.0	5.0
6	5.0	5.0	6.0	6.0	5.0	5.0
7	5.0	7.0	7.0	7.0	5.0	5.0

List of Figures

Figure 1.

Summary of procedures

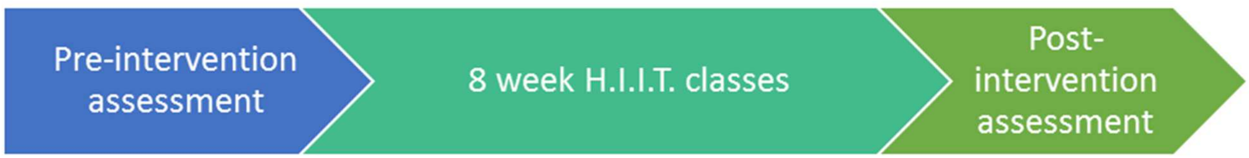

Figure 2.

Maximum correct span on the PEBL reverse digit span task

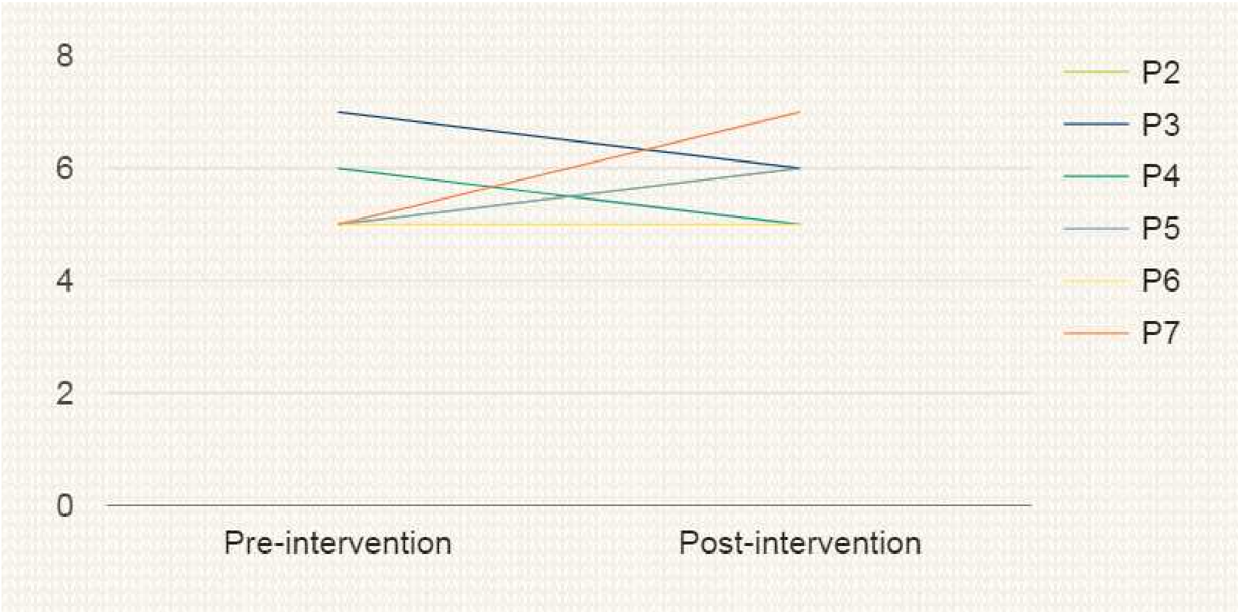

Figure 3.

Maximum correct span on the PEBL visual-response memory span task

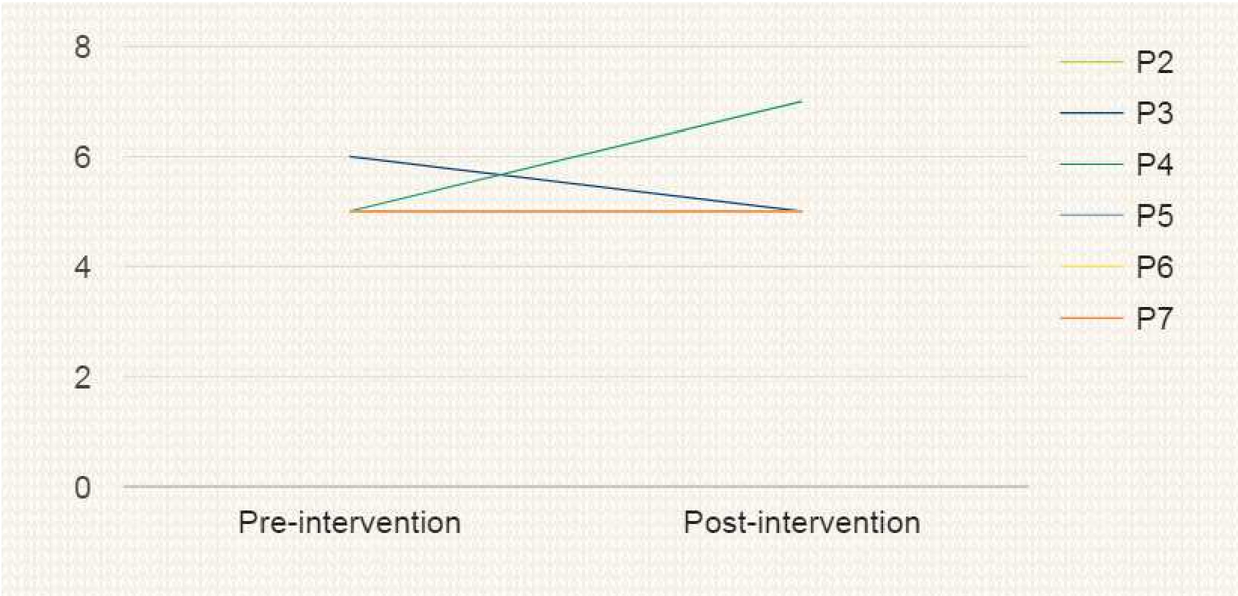

Figure 4.

Maximum correct span on the PEBL symmetry span task